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Banks' Interest Rate Risk

—

Pricing and Risk Management

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In memory of my dad

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Abbreviations

2- (3-)SLS	Two- (Three-) stage least squares
Avg.	Average
BaFin	Bundesanstalt für Finanzdienstleistungsaufsicht
BHC	Bank holding company
CAMELS	Capital adequacy, Asset quality, Management quality, Liquidity, and Sensitivity to market risk
CDS	Credit default swaps
CEO	Chief executive officer
CFO	Chief financial officer
Endog.	Endogenous
EUR	Euro
Exog.	Exogenous
FE	Fixed effects
GDP	Gross domestic product
HAC	Heteroskedasticity and autocorrelation
HGB	Handelsgesetzbuch
HHI	Herfindahl-(Hirshman) index
IEM	Interest expense margin
IIM	Interest income margin
IIP	Implicit interest payments
IRR	Interest rate risk
KWG	Kreditwesensgesetz
LGD	Loss given default

LIBOR	London interbank offered rate
LM	Lagrange multiplier
LPM	Linear probability model
NII	Non-interest income
NIM	Net interest margin
nu	Not used
OBS	Off-balance-sheet
OCR	Opportunity cost of reserves
OIS	Overnight index swaps
OLS	Ordinary least squares
PD	Probability of default
P&L	Profit and loss
p-val.	Probability value
ROE	Return on equity
RWA	Risk-weighted assets
S&L	Savings and loan (association)
stat.	Statistic
TA	Total assets
Underid.	Underidentification
U.K.	United Kingdom
U.S.	United States

List of Symbols

$a^{(*)}$	(Optimal) Mark-up charged on deposits
Adj. R^2	Adjusted R-squared (coefficient of determination)
$b^{(*)}$	(Optimal) Mark-down charged on loans
$BExp$	Average board experience (variable)
BM	Bank margin (dependent variable)
BS	Vector of bank-specific explanatory variables
$C_{L;D}$	Operating cost for loans and deposits, respectively
CL	(Share of) Customer loans (variable)
CR^2	Generalized R-squared for censored and limited dependent data
D	Market value of all deposits
D_{gap}	(Modified) Duration gap
DG	(Modified) Duration gap (variable)
$D_{mod}^{A;L}$	Modified duration of banks' assets and liabilities, respectively
$EU(W)$	Expected utility of the wealth level
GR^2	Generalized R-squared
IMR	Inverse Mills ratio (variable)
L	Market value of all loans
LC	Loan commitments (variable)
M	Market value of money market funds
mc	Marginal cost
ME	Vector of macroeconomic explanatory variables
N	Number of observations, or cross-sectional units
$N_3(\mathbf{0}, \sum)$	Trivariate normal distribution with mean 0 and variance-covariance

	matrix $\sum$
$p_{L;D}$	Fair market price of a loan and deposit, respectively
$P_{L;D}$	Price of a loan and deposit, respectively, set by the bank
PSE	Past interest rate swap experience (dummy variable)
$Q_{L;D}$	Volume of new loan demand and deposit supply, respectively
r	(One-period) Rate of return on money market funds
$r_{L;D}$	Expected (one-period) rate of return on loans and deposits, respectively
RP	Vector of revolving portfolios (explanatory variables)
SE	Swap extent (variable)
SU	Swap use decision (dummy variable)
t	Index for the time period
T	End of period planning horizon
TM	Vector of explanatory variables determined by a theoretical model
$U(')'\left(\overline{W}\right)$	First (Second) derivative of the utility function around the expected level of end of period wealth
W	Initial wealth of a bank
X	Vector of common explanatory variables in a system of simultaneous equations
$\tilde{Z}_{I;C;D}$	Stochastic risk terms for the interest rate and credit risk in loans, and the interest rate risk in deposits
$\alpha_{L;D}$	Likelihood of new loan demand and deposit supply, respectively, given "fair" pricing with no bank fees
$\beta_{L;D}$	Reduction factor in the likelihood of new loan demand and deposit supply due to the pricing of bank fees
ΔEU	Difference in expected utility
$\lambda_{L;D}$	Poisson process intensity of a new loan demand and deposit supply, respectively, occurring
$\sum$	Variance-covariance matrix
$\sigma^2_{I;C;D}$	Volatility of the rate of return on loans due to interest rate and credit risk, and on deposits due to interest rate risk

$\sigma_{IC;ID;CD}$	Covariance between the interest rate and credit risk in loans, the interest rate risk in loans and deposits, and the credit risk in loans and the interest rate risk in deposits, respectively
0	Subscript for the initial values at the beginning of the period

Chapter 1

Introduction

This thesis covers an extended overview about interest rate risk (IRR) in general and two essays on theoretical and empirical financial intermediation covering the pricing and risk management of banks' IRR exposure. It investigates how banks should optimally price the IRR stemming from maturity transformation into loan and deposit rates and whether such optimal behavior can be found in bank interest margins. Moreover, it addresses the question of how IRR hedging off the balance sheet affects their maturity transformation. This chapter gives an extended overview of the literature dealing with financial intermediaries' IRR management and briefly introduces the following chapters.

The main task of financial intermediaries — such as commercial banks — is the transformation of risks between lenders and borrowers of funds. When accepting deposits and handing out loans financial intermediaries take on credit risk as some borrowers might not succeed with their projects and therefore fail to repay their loans. Additionally, banks are exposed to liquidity and maturity risk by transforming deposits — that can be withdrawn anytime — into long-term loans. Liquidity and interest rate risk are closely related. The main difference between maturity and liquidity risk is the repricing frequency of assets and liabilities (e.g., Brunnermeier and Yogo, 2009). Together with the transformation of investment size, as a single borrowers' loan is usually funded with the deposits from several saving accounts, these tasks are known as qualitative asset transformation (e.g., Bhattacharya and Thakor, 1993; Freixas and Rochet, 2008).

As financial intermediaries' core business is inherently associated with risk taking, risk management is an essential task. The most obvious way of risk management is an adequate measurement of the risks undertaken and their interconnection. Knowing the risks, banks can price them into loan and deposit rates so that they earn a risk premium over the risk-free rate, which compensates them for expected losses and pays shareholders a return on equity. Credit risk can be reduced by diversification (Diamond, 1984), but liquidity risk and IRR cannot be fully diversified away, but only allocated between parties. Nowadays, securitization allows banks to lay off all risks associated with assets to the capital markets, and off-balance sheet (OBS) transactions enable banks to trade risks with counterparties. Derivatives easily permit banks to hedge the non-diversifiable interest rate and currency risk via forwards, futures, and swaps. Credit risk is now increasingly managed using credit default swaps (CDS) and related products.

IRR measures the extent to which a bank is affected by changes in market interest rates. There are two ways in which IRR can have an impact on banks. The first is the valuation risk that assets, liabilities and OBS positions change their market values with an unfavorable impact on the bank's economic value — often expressed as the market value of equity. Alternatively, a cash flow risk perspective can be taken, which is consistent with the value perspective as the sum of discounted cash flows should equal the economic value (English, 2002). Most often, interest income and expenses are then examined. Valuation risk is more closely related to the balance sheet, whereas the effects of cash flow risk become more visible in the profit and loss (P&L) statements. In general, with a positive duration gap — when the maturity of assets exceeds the maturity of liabilities — an increase in market rates leads to a deterioration in the market value of equity as market value in assets declines more heavily compared to liabilities. Furthermore, as liabilities mature more frequently or have to be repriced, interest expenses rise more heavily compared to income and profitability decreases. This risk from a cash flow perspective is also referred to as the refinancing risk, or because of its close alignment with liquidity risk, as roll-over risk if liabilities — such as wholesale funding — cannot be refinanced at all.

IRR can have different sources. Among them are repricing risk, yield curve risk, and basis risk. Repricing risk exists when assets and liabilities have different sensitivities to changes in market rates due to different maturities, repricing frequencies, base rates for floating-rate positions, discretion for positions where the bank is allowed to adjust rates at will, and bank customers' implicit options to repay loans and withdraw deposits in response to the interest rate environment. Yield curve risk refers to the risk that the yield curve does not change all relevant market rates to the same extent but the shape of the yield curve has a different impact on assets and liabilities, even though they might have the same sensitivities to IRR. Finally, basis risk evolves when floating-rate instruments are adjusted to differing market rates, known as base rates (English, 2002).

Although banks' IRR exposure received most attention during the S&L crisis ranging from the 1980s until the mid-1990s in the U.S., the global financial crisis, that started with the U.S. subprime crisis, has put much attention to banks' liquidity risk, especially the roll-over risk caused by wholesale funding (e.g., Acharya and Merrouche, 2013). However, with the beginning of the current decade banking supervisors have again shifted their focus on banks IRR exposure. Donald L. Kohn, a vice chairman of the Board of Governors of the Federal Reserve System announced his concerns in a speech at the Federal Deposit Insurance Corporation in January 2010 (see, Kohn, 2010). Although central banks are willing to supply liquidity at extraordinary low rates for the next years, they will have to raise rates when their economies have recovered at some point of time. Researchers at the International Monetary Fund share this belief and regard higher levels of short-term rates as a macroprudential mechanism of financial stability (Blanchard et al., 2010). However, raising rates would serve as an interest rate shock and would hit banks with a positive maturity mismatch (Kohn, 2010). A change in central bank policy could then have similar effects as at the beginning of the S&L crisis when a policy of monetary tightening increased short-term rates in the U.S.

Similarly, the Deutsche Bundesbank announced in their 2010 Financial Stability Report concerns of banks increasing their maturity gaps drastically in the aftermath of the Lehman crisis (Deutsche Bundesbank, 2010). As savers searched for safe havens, the smaller savings and cooperative banks, in particular, experienced enormous inflows of short-term savings deposits that enforced these banks' maturity gaps. The drop in short-term rates, while the long-term rates remained comparatively stable, steepened the slope of the yield curve and gave banks incentives to keep the resulting IRR in their banking books. At the same time the BaFin announced to put more scrutiny on banks with high IRR and to consider requiring additional capital from these banks (see, Osman et al., 2010). Finally, in November 2011 the Bundesbank tightened the regulation for German commercial banks' IRR in the banking book. The interest rate shock banks have to simulate was increased from 130 basis points to 200 basis points while the maximum loss of regulatory capital remained constant (Deutsche Bundesbank, 2012). To summarize the recent developments, although IRR is not present in discussions as much as liquidity risk is, it still plays an important role in the overall risk financial intermediaries take, and is still a central issue in banking regulation.

Chapter 2 provides a literature overview on banks' IRR and describes how the two essays contribute to the literature. Chapter 3 presents the essay on how banks price the risk and expected returns arising from maturity transformation into their interest income and expenses. Chapter 4 investigates how the simultaneous use of interest rate swaps affects banks' duration gap.

Chapter 2

Literature on Interest Rate Risk and Hedging

IRR is a major source of market risk in commercial banking and therefore regulators demand prudent supervision. In contrast to credit risk, no extra capital generally has to be set aside for IRR. Nevertheless, the national regulators can enforce an increase in regulatory capital for banks with excessive IRR (Basel Committee on Banking Supervision, 2004). The dangers of excessive interest rate risk taking with the potential to destabilize a whole financial system became apparent with the onset of the savings and loan (S&L), or thrift, crisis of the 1980s to mid-1990s in the U.S.[1] The crisis started with short-term rates and rate volatility soaring in the early 1980s. Most savings banks had granted long-term fixed-rate loans and were funded with demandable deposits. Deposit rate ceilings did not allow savings and loan associations to adjust their rates to market rates. By the mid-1980s most of these banks were de facto insolvent, but nevertheless were allowed to keep operating (Barth, 1991). Today, they would be referred to as zombie banks. Expansion of deposit insurance and the deregulation of the industry only relaxed the income situation of the S&Ls in the short term, but provided several incentives for moral hazard that finally resulted in the crisis (Kroszner and Strahan, 1996). Several savings and loan associations failed and depositors would have suffered severe losses (James, 1991) if the

[1] See, Gupta and Misra (1999) for a survey on the S&L crisis.

government had not paid the cost of up to $150 billion with taxpayers' money (Gupta and Misra, 1999).

With the beginning of the thrift debacle, the sensitivity of bank lending to shocks in the monetary policy rate attracted attention. The outflow of deposits during times of rising prime rates, such as the Federal funds rate in the U.S., forces banks to reduce their granting of new loans. In the literature, this is known as the bank lending channel (Bernanke and Blinder, 1992) and generally focuses on changes in aggregate lending. Hitherto, the literature has chiefly emphasized the importance of size (Kashyap and Stein, 1995), capital (Kishan and Opiela, 2000), liquid assets (Kashyap and Stein, 2000), and internal capital markets within conglomerate banking firms (Campello, 2002) in mitigating the impact of monetary shocks. However, a small group of papers directly addresses the influence of the maturity mismatch on lending volume.

These studies have their roots in the theoretical model provided by van den Heuvel (2002). The author provides the link from income and losses and capital accumulation to banks' lending behavior. Empirically, the impact of maturity transformation within the bank lending channel has been tested by Gambacorta and Mistrulli (2004), who prove that banks with a higher exposure to IRR decrease lending more drastically. These authors are the first to use a very detailed measure of the maturity gap, apart from the one-year repricing gap which has commonly been employed as a proxy (e.g., Flannery and James, 1984). When focusing on the price-setting behavior of banks, Gambacorta (2008) reports that banks with a larger maturity mismatch increase loan and deposit rates more drastically. The increase in loan rates dominates the increase in deposits in order to compensate banks for declining profitability when a higher volume of deposits reprices compared to loans. Recently, Landier et al. (2012) confirm that banks with a higher sensitivity to IRR cut back lending more drastically when affected by a hike in short-term rates. However, the banks hit are also the ones that increased their duration gap drastically in the four years before the monetary tightening. Black and Rosen (2011) show that banks not only decrease their new lending but also change its composition. During periods of monetary tightening, banks tend to hand out new loans with significantly shorter maturity than before, thereby reducing their on-balance exposure to IRR via a reduction of the duration gap. Again, this effect is stronger for banks that initially had a larger maturity mismatch. In Germany, savings and cooperative banks use their interbank lending structures with their affiliated head institutions, for example, the Landesbanken for savings banks, as internal capital markets comparable to bank holding company (BHC) structures in order to manage their on-balance-sheet exposure to IRR (Ehrmann and Worms, 2004).

Another link between the level of the monetary policy and bank lending has been put forward in the risk-taking channel (Borio and Zhu, 2012). Low levels of interest rates lead to a "search-for-yield" into riskier investments (Rajan, 2006). In the years before the onset of the financial crisis, banks have systematically lowered their lending standards in response to the monetary policy rate (Maddaloni and Peydró, 2011) and accepted less credit-worthy borrowers. This credit-risk-seeking behavior is induced by the transmission of the monetary policy rate to short-term yields and not to long-term yields (Jiménez et al., 2012).

Farhi and Tirole (2012) and Stein (2012) show that an excessive supply of liquidity by central banks can lead to maturity transformation of systemic risk exposure. The regulator can either limit such behavior by introducing reserve requirements or is committed to bailing out the banks for too-many-to-fail reasons. Hence, the risk-taking channel works not only through enhanced credit risk but also through maturity transformation as a byproduct of liquidity creation. Furthermore, a reversion of central banks' current low interest rate policy can serve as an interest rate shock with the consequences described above.

In summary, although the financial crisis that started with the U.S. mortgage crisis drew much of regulators' attention to liquidity risk and leverage, IRR is still an important issue in banking supervision. Below, I will briefly introduce each chapter and describe how the results contribute to the literature.

Pricing of interest rate risk

Banks will charge a risk premium for the maturity mismatch they are willing to accept in order to supply liquidity. The theoretical literature on the determinants of banks' interest margin, i.e. the difference between the rate charged on a single type loan less the rate paid on a prototype deposit, can be separated into two strands. The first is the "dealership approach" that has its roots in the pricing decisions of security dealers optimizing their bid/ask spread (Stoll, 1978; Ho and Stoll, 1981). The second strand are the "cost-of-good-sold" models. Their foundation lies in the banking firm literature that regards deposits as an input to produce loan output (e.g., Klein, 1971; Monti, 1972; Sealey, 1980). The second strand treats the cost of funding, i.e. deposit rates; as stochastic, whereas the dealership models consider deposit rates an endogenous variable that banks maximize simultaneously with loan rates.

The dealership model in banking emerged with the seminal study of Ho and Saunders (1981), and therefore all related models are also referred to as Ho-Saunders type models. Ho and Saunders (1981) derive a model which explains a bank's pricing decisions when the bank is faced with endogenous demand for loans and supply of deposits. The gap between loans and deposits is funded via (invested in) the money market. The main result is that banks' increase their intermediation margin with the uncertainty in money market rates. Several models have extended the initial one, and shifted the uncertainty from the long-term rates driving the market values of loans and deposits to the short-term money market rates (McShane and Sharpe, 1985), included the credit risk of loan default (Angbazo, 1997), and the operational cost of offering intermediation services (Maudos and Fernández de Guevara, 2004). Additionally, the impact of cross-selling between two different asset types has been investigated (Allen, 1988; Carbó and Rodríguez, 2007).

Cost-of-good-sold models included operating cost from the outset and derived their results under differing forms of Arrow-Pratt risk aversion (Zarruk, 1989), capital regulation and deposit insurance (Zarruk and Madura, 1992), and stronger forms of risk aversion as well as credit risk (Wong, 1997). The impact on the intermediation margin with regard to model features that are also included in the Ho-Saunders type models are, in general, identical, although they depend on the form of risk aversion the bank faces.

Cost-of-good-sold models are pure theoretical contributions that derive comparative statics of the determinants of bank interest margins. In contrast, the Ho-Saunders type models — except for Allen (1988) — are tested empirically for different countries, time periods, and bank margins, although they are most frequently applied to the net interest margin as an accounting measure of bank income from classical financial intermediation business.

In Chapter 3 *"Determinants of Bank interest Margins: Impact of Maturity Transformation"*, which is joint work with Oliver Entrop, Christoph Memmel, and Marco Wilkens, an extension of the Ho-Saunders model is introduced that explicitly takes maturity transformation into account by introducing fixed-rate loans with a longer maturity than deposits. We use a notation of the model in market values (Ho and Saunders, 1981; Allen, 1988) and therefore not only allow for refinancing risk of rising interest rates. Our model also captures the valuation risk that the market value of loans declines more heavily compared to deposits given a positive parallel shift in the yield curve. This would lead to a deterioration in the market value of equity. In practice, most supervisors monitor IRR as a maximum loss of equity given a standardized interest rate shock. By allowing the financial intermediary to charge the fees to cover the risk premia in advance (Freixas and Rochet, 2008), our model also shows how banks' pricing decisions are affected by their expectations of financial gains from maturity transformation. Our model is then tested for the first time on a sample of the German commercial banks between 2000-2009. We are the first to test the Ho-Saunders type models predictions separately for interest income and expense margins. Our findings suggest that the effects found for the net interest margin rely heavily on the pricing of assets where banks charge premia for bearing maturity-related IRR, but are also willing to pass parts of the profits expected from maturity transformation back to borrowers. On the liability side, the theoretically derived effects are more weakly pronounced and insignificant for most samples investigated.

Off-balance sheet interest rate risk management

The vast majority of, both, the theoretical and empirical hedging literature has focused on corporate hedging decisions and their determinants. In a seminal study Smith and Stulz (1985) show that hedging lowers cash flow variability. Without adequate cash flows a company might have to forgo valuable investment projects. Froot et al. (1993) endogenize the cost of bankruptcy by assuming that internally generated funds are cheaper compared to raising external capital. Additionally to bankruptcy risk, also liquidity risk is a major determinant of hedging decisions (e.g., Mello and Parsons, 2000). Liquidity is of enormous importance as the payments to counterparties from derivatives transactions designed to decrease cash flow variability can trigger bankruptcy in states of low cash reserves (e.g., Rampini et al., 2012). Such effects may result in rationale market timing and gambling behavior of financially constrained firms (Bolton et al., 2013). The research on bank hedging is compared to corporate hedging of more limited size.

The focus of Chapter 3 has been how banks price IRR. Financial intermediation theory stresses that banks should manage and price only those risks where they possess a monitoring advantage, but hedge all other risks. Therefore, banks should focus on credit risk (Diamond, 1984; Froot and Stein, 1998) and the liquidity risk of early deposit withdrawal (Hellwig, 1994). Our Ho-Saunders type model explained that it is not necessary to hedge all IRR from loans and deposits, but that a balance-sheet hedge exists, where liabilities do partly offset the IRR from the asset side.

In Chapter 4 *"Market Timing, Maturity Mismatch, and Risk Management: Evidence from the Banking Industry"*, which is joint work with Oliver Entrop, Thomas Kick, and Marco Wilkens, we empirically investigate German commercial banks' IRR management by simultaneously examining their on-balance-sheet and off-balance-sheet activities. The research is based on the study conducted by Purnanandam (2007) for the U.S. banking industry, and employs the estimators Chernenko and Faulkender (2011) used to explain corporates' hedging and speculative attempts when entering into interest rate swaps. The study adds to the literature on how banks manage IRR off the balance sheet. Our findings are generally in line with Purnanandam. The only exemption is found for the impact of liquid assets on the propensity to use interest rate swaps. Differences between bank-based and market-based financial systems in managing liquidity and interest rate risk through liquid assets have been stressed by Allen and Gale (1997).

Although interest rate swaps are ideal for hedging IRR, they can also be used to speculate on interest rate movements (e.g., Faulkender, 2005). A mild form of speculation — which is, at the same time, related to hedging — is market timing when entering or closing swap positions. Such behavior refers to market views incorporated into risk management decisions and is therefore also described as selective hedging. In line with expectations, we find that banks are less likely to hedge with interest rate swaps when a steep yield curve offers extra profits from maturity transformation. Uncertainty in the interbank markets, however, induces banks to increase the extent of their IRR hedging. Consistent with the bank risk taking channel, we find that banks hedge more when, at the same time, high short-term rates make even short-term lending profitable.

The key finding of the study stems from tests of the endogeneity assumptions underlying the simultaneous equations framework. Naturally, it would be assumed that the decisions on the magnitude of the maturity mismatch and the extent of interest rate swaps are endogenous decisions in managing the net IRR exposure. However, Durbin-Wu-Hausman type tests cannot reject an exogenous relation for the decision to use interest rate swaps as well as the extent of their use to the duration gap, except for banks that start using swaps for the first time. We regard our results as driven by two effects: First, the maturity gap is largely determined by borrowers' liquidity needs, and the provision of long-term maturity is facilitated by the high-standard property laws prevailing in Germany. Second, the use of interest rate swaps, as the most common way to hedge IRR off the balance sheet, is determined by the IRR regulation prevailing in Germany which has a fixed threshold when it considers banks as "outliers" with excessive IRR.

Chapter 3

Determinants of Bank Interest Margins: Impact of Maturity Transformation*

Abstract

This paper explores the extent to which interest risk exposure is priced in bank margins. Our contribution to the literature is twofold: First, we extend the Ho and Saunders (1981) model to capture interest rate risk and expected returns from maturity transformation. Banks price interest risk according to their individual exposure separately in loan and deposit intermediation fees, but reduce (increase) these charges for loans (deposits) when positive excess holding period returns from long-term exposures are expected. Second, we test the model-derived hypotheses not just for the commonly investigated net interest margin but also for interest income and expense margins separately in a sample encompassing the German universal banking sector between 2000 and 2009. We find that banks price their individual interest rate risk and corresponding expected excess holding period returns via the asset side into the net interest margin. For liabilities, we find interest rate risk exposure is only priced by smaller, local banks.

* This chapter is based on the working paper *Determinants of Bank Interest Margins: Impact of Maturity Transformation* by Entrop et al. (2012).

3.1 Introduction

The theory of financial intermediation attributes a number of activities, commonly referred to as qualitative asset transformation, as core functions to banks (e.g. Bhattacharya and Thakor, 1993). These activities encompass credit risk, liquidity and maturity transformation.[2] Maturity transformation evolves in most cases as a consequence of liquidity provision when fixed-rate long-term loans are financed using short-term deposits. The resulting maturity gap can be attractive to banks when term premia are present in the yield curve — representing the well known “lure of interest rate risk” (Greenbaum and Thakor, 2004, p. 138) — but it also increases their interest rate risk (IRR) exposure. This exposure can be distinguished with regard to its effects in two forms (Hellwig, 1994): First, *reinvestment opportunity risk*, i.e. the risk of having to roll over maturing contracts at a possibly disadvantageous rate. Second, *valuation risk*, i.e. the risk that changes in the yield curve reduce the net present value of a bank’s loan and deposit portfolio.

Recent financial intermediation theory suggests that banks operate with too high maturity mismatches (e.g. Segura and Suarez, 2012; Brunnermeier and Oehmke, 2012). Although these models focus on financial intermediaries’ vulnerability to liquidity shocks like the current financial crisis, they additionally verify intermediaries’ exposure to increasing interest rates in “normal” times due to the interlinked roots of liquidity and maturity transformation.[3] Recently, discussions about the existence of the bank risk-taking channel (Borio and Zhu, 2012), i.e. that low levels of nominal policy rates induce financial intermediaries to take higher risks (and increase leverage), have gained attention. Therefore, discussions of new macroprudential regulatory frameworks include linking monetary policy and banking regulation in such a way that central banks should be prompted to consider higher policy rates once the current turmoil is over (e.g. Blanchard et al., 2010).

[2] We will use the notion of maturity and term transformation interchangeably. Although maturity is not the appropriate risk measure, maturity transformation evolved as a synonym for what can be referred to more generally as term transformation. Bhattacharya and Thakor (1993) have already addressed this issue.

[3] For a brief theoretical comparison of interest rate and liquidity risk management see Brunnermeier and Yogo (2009).

Rising interest rates in response to such a change in central bank policy would directly result in the aforementioned consequences of IRR.

Seminal models such as Ho and Saunders (1981) and Froot and Stein (1998) imply that banks should charge intermediation fees for the risks they keep on-balance. This paper examines the nexus between banks' involvement in maturity transformation, their profitability, and the intermediation fees they charge as risk compensation. First, we present a theoretical model that allows an analysis of the determinants influencing fees when banks engage in maturity transformation. Second, we test the model-derived hypotheses empirically by examining bank margins.

For our analysis, we extend the dealership model initially developed by Ho and Saunders (1981) to determine the factors that influence intermediation fees when a bank's balance sheet shows maturity mismatch. In the original Ho/Saunders model, a bank is viewed as a pure intermediary between lenders and borrowers of funds that sets prices in order to hedge itself against asymmetric inflows and outflows of funds. Assuming loans and deposits have an identical maturity, IRR only arises when loan volume does not match deposit volume, and the existing volume gap is closed using short-term money market funds. Rolling over maturing short-term positions creates reinvestment (refinancing) opportunity risk. Maximizing expected utility, the bank charges fees that increase with the volatility of interest rates as a means of compensation for the potential losses.

We relax the assumption of equal loan and deposit maturity. In our model, loans and deposits cannot then perfectly offset IRR, and exposure is not solely determined by interest rate volatility, but additionally by the bank-individual exposure captured in the bank's maturity structure, i.e. its maturity gap. As a consequence, banks increase both loan and deposit fees with increasing interest rate volatility, but they additionally increase (lower) loan (deposit) fees with the size of the positive maturity mismatch. The economic rationale behind the latter is that banks with higher interest risk exposure from holding long-term loans in their portfolios charge higher loan fees as risk compensation and bid more aggressively on deposits by lowering deposit fees rather than having to refinance themselves in the very short-term money market.

However, when positive valuation gains — so-called positive “holding period returns” above the money market rate — from long-term exposures are expected, banks partly reverse their pricing behavior, i.e. they lower (increase) loan (deposit) fees. The rationale is that banks are already partly compensated for taking the risk from long-term loans by these returns in expectation, which allows them to charge lower fees. For deposits, which are also characterized by longer maturity than the money market account, the opposite holds as this represents a liability position.

The sum of the loan and deposit fees is the net fee income which increases with interest rate volatility and maturity mismatch and decreases with positive expected excess holding period returns from maturity transformation, given banks have a positive maturity gap.

For the empirical analysis about the impact of maturity transformation on bank fees and their determinants, we utilize a comprehensive dataset of the entire German universal banking sector between 2000 and 2009. The German banking system is well-suited for this analysis. First, as Germany is a bank-based financial system (e.g. Schmidt et al., 1999), the majority of liquidity is provided via maturity transformation by financial intermediaries. The predominance of (long-term) fixed-rate loans intended to be held till maturity instead of being securitized, and the high dependence on (demand and especially savings) deposits are specific characteristics of the German banking sector. Therefore, German banks seem prone to IRR from maturity transformation (Memmel, 2011). Second, IRR management is conducted more frequently on-balance compared to market-based financial systems that rely more heavily on derivatives hedging.[4] Risk management is implemented through buffer stocks of liquid assets and the intertemporal smoothing of non-diversifiable risks (Allen and Santomero, 2001), such as liquidity and interest risk, as well as interbank lending in bank networks. The latter shield (smaller) banks in ma-

[4] Allen and Santomero (2001) explain this difference between market-based systems, such as the U.S., and bank-based systems, such as Germany, drawing on the model of Allen and Gale (1997). The lack of competition from financial markets is considered to be the basis for German financial intermediaries' ability to manage risk on-balance. Purnanandam (2007) finds that small U.S. commercial banks likewise manage IRR less frequently via derivatives, but on-balance by adjusting their maturity gap to interest rate changes.

jor banking groups against monetary contractions, without having to reduce lending as a consequence of large deposit outflows and drastic balance sheet duration adjustments (Ehrmann and Worms, 2004).

In our empirical analysis we not only test the impact of the optimal loan and deposit fee determinants on the commonly investigated net interest margin (NIM), but also are the first to test the hypotheses for the the asset and liability side, i.e. interest income and expense margins (IIM and IEM), separately. As model-derived optimal intermediation fees economically represent the difference between bank-set interest rates and fair market rates of the same maturity, we use detailed supervisory data on bank assets' and liabilities' maturities to create maturities-mimicking bond portfolios whose coupon payments control for the impact of market rates on the respective margins in our analysis. This procedure allows us to separate the impact of the theoretical determinants on the fee-part of the margins.

We find the empirical results for the NIM to be consistent with our model-hypotheses, i.e. net intermediation fees increase with the maturity gap and decrease with expected returns from maturity transformation; however the effects of the expected return from maturity transformation are minor. All margins positively depend on interest rate volatility. Disentangling the NIM into IIM and IEM, we find strong evidence that banks price their maturity gap and corresponding expected returns on the asset side; however, we find the model-implied effects on the liability side only for cooperative banks. Our results, therefore, imply that the effect found for the NIM are mainly driven by the asset side.

The remainder of the paper is organized as follows. Section 3.2 reviews the related literature on determinants of bank interest margins in Ho/Saunders-type models. In Section 3.3 we derive the theoretical model with differing loan and deposit maturities. An overview of the data and the institutional characteristics of the German commercial banking sector is provided in Section 3.4, where the variables used to proxy for the derived determinants are also introduced. Section 3.5 presents the econometric model (Section 3.5.1) and the empirical results. Institutional differences in the banking sector are taken into account by investigating three different sub-samples, for savings, cooperative and other, mainly private commercial, banks. First, we examine the commonly investigated net interest margin (Section 3.5.2), and then separately the interest income and expense margin (Section 3.5.3). Section 3.5.4 investigates the extent to which the previously derived results are robust with respect to the financial crisis. Section 3.6 presents our concluding remarks.

3.2 Related Literature

This paper is most related to the literature dealing with Ho/Saunders-type models. Ho and Saunders (1981) model a monopolistic, risk-averse bank acting solely as an intermediary between lenders and borrowers of funds. Over a single-period planning horizon, the bank's objective is to maximize its utility of terminal wealth by charging demanders of loans and suppliers of deposits fees for providing them with intermediation services. The bank hands out a single type of loan and accepts a single type of deposit, which are assumed to have the same maturity. Thus, financing all loans using deposits completely eliminates IRR. Intermediation services encompass the provision of immediacy, i.e. accepting every transaction immediately, and not waiting until the opposite transaction arrives to offset the risk. The lack of (excess) funds when new loans are demanded (deposits are supplied) forces the bank to adjust its money market positions. The maturity of the money market is assumed to be short-term, below that of loans and deposits, and identical to the decision period. At the end of the decision period, money market accounts have to be rolled over. Short (long) positions — a consequence of the loan exceeding (falling below) the deposit volume — expose the bank to the refinancing (reinvesting) risk of rising (falling) rates. For this reason, the fees charged should cover potential losses from rolling over short-term funds.

A series of authors have extended the model: McShane and Sharpe (1985) shift interest uncertainty from loan and deposit returns to money market rates. Switching the source of risk involved a change from price to rate notation, which succeeding authors adopted.[5] Allen (1988) considers two different types of loans with interdependent demand functions.

[5] The change of the source of risk in McShane and Sharpe (1985) was motivated by the predominance of variable-rate loans and deposits in Australia (p. 116, footnote 2).

Carbó and Rodríguez (2007) regard this second asset as a non-traditional activity and investigate how specialization and cross-selling behavior between assets influence several bank spreads instead of focusing solely on interest margins. Angbazo (1997) additionally attaches credit risk to the interest rate risk associated with the bank's loan, and derives a risk component that does not only depend on the volatility of risk sources, but also on the co-movement thereof. The operating cost necessary to provide intermediation services is taken into account by Maudos and Fernández de Guevara (2004). Finally, Maudos and Solís (2009) combine the independently derived two-asset-type models and all other extensions into a single integrated model.

3.3 Theoretical Model

In this section, we present an augmented dealership model of Ho and Saunders (1981) that explicitly includes maturity transformation due to loan maturity exceeding deposit maturity. To incorporate the resulting valuation risk, loans and deposits are modeled as fixed-rate contracts with different maturities, and thus with different sensitivities to changes in the yield curve. We adopt the price notation of Ho and Saunders (1981) and Allen (1988), and focus on the provision of a single loan and a single deposit to keep the bank's risk management decision simple.

The bank sets prices at which it is willing to grant loans (P_L) and take in deposits (P_D) at the beginning of the decision period before the demand for loans and the supply of deposits can be observed, and does not adjust them afterwards. Fees are set as mark-ups a on deposits, and mark-downs b on loans, in relation to what the bank considers the "fair" price , p_D and p_L, of the given transaction:

$$P_D = p_D + a, \qquad P_L = p_L - b. \tag{3.1}$$

The fair price can be best thought of as the price of a coupon-paying bond with identical risk characteristics as the underlying transaction. Assuming that only loans bear credit risk, their fair price p_L is that of a (corporate) bond with identical probability of default and recovery rate, whereas the fair price of a deposit p_D corresponds to a default-free (government) bond of identical maturity.

We assume that the bank charges (demands) rates equaling par yields, i.e. fair market rates, of the underlying bond which implies the fair price of a new transaction is at par when it is initiated. Consequently, the cost (and profits) of financial intermediation are solely accounted for by the magnitude of the up-front fees a and b. Mark-ups a on deposits and mark-downs b on loans result in an effective yield to maturity below that of bond funding for deposits, and above that of bond investing for loans.[6]

The bank's initial wealth portfolio W_0 at the beginning of the period consists of three different portfolios: (i) long positions in loans L, (ii) short positions in deposits D, and (iii) money market funds M, which can take either long or short positions, all denoted in market values:

$$W_0 = L_0 - D_0 + M_0. \tag{3.2}$$

The length of the planning horizon T is shorter than the maturities of the loans and deposits. Thus, the value of the loan and deposit portfolios in T are random due to unexpected changes in the yield curve or in default risk, i.e. the returns until T of both the loan and the deposit portfolio are subject to IRR, and the loan return additionally to credit risk. Returns are the returns of the underlying bonds since intermediation fees are not considered as they are charged in advance. Loans generate an expected rate of return of r_L, and deposits of r_D until T. The uncertainty of returns will be captured in stochastic terms $\tilde{Z}$. Interest rate risk in loans will be displayed as $\tilde{Z}_I$, credit risk as $\tilde{Z}_C$, and interest rate risk in deposits as $\tilde{Z}_D$. All stochastic terms have an expected mean of zero and are trivariate normally distributed $N_3(\mathbf{0}, \sum)$, with variance-covariance matrix $\sum$. If loan maturity is assumed to exceed deposit maturity, normally-shaped yield curves

[6] To illustrate bank pricing decisions, we give an example. Let us assume the bank offers a two year deposit and the par yield of a two year bond equals 3%. The bank will pay this fair interest rate to its depositors. However, the bank charges up-front intermediation fees a of, let us say, 1.5%, i.e. any depositor has to hand in \$101.5 for a claim guaranteeing the repayment of \$100. By doing this, the bank decreases the effective yield to maturity paid on deposits below the fair market rate of 3%.

lead, in general, to higher (expected) returns on long-term bonds compared with short-term bonds, i.e. $r_L > r_D$. In this case, loan values are more sensitive to changes in the yield curve, and their return volatility is larger than that of deposits, i.e. $\sigma_I^2 > \sigma_D^2$. The rate of return on the money market account, on the contrary, is certain over the period and denoted r.

Managing loan and deposit portfolios generates operating cost C each period, which are monotonically increasing functions of the market values of the loan and deposit portfolios. The bank's end-of-period wealth is given by:

$$W_T = \left(1 + r_L + \tilde{Z}_I + \tilde{Z}_C\right) L_0 - \left(1 + r_D + \tilde{Z}_D\right) D_0 + (1 + r) M_0 - C(L_0) - C(D_0). \tag{3.3}$$

The bank maximizes expected utility. The utility function $U(W)$ is twice continuously differentiable, with $U' > 0$ and $U'' < 0$ in order to reflect risk aversion. In line with the previous literature, the expected end-of-period utility, $EU(W)$, is approximated using second-order Taylor series expansion around the expected level of $E(W) = \overline{W}$ and given by:

$$EU(W) = U\left(\overline{W}\right) + \frac{1}{2}U''\left(\overline{W}\right)\left[\left(\sigma_I^2 + 2\sigma_{IC} + \sigma_C^2\right) L_0^2 - 2\left(\sigma_{ID} + \sigma_{CD}\right) L_0 D_0 + \sigma_D^2 D_0^2\right], \tag{3.4}$$

where σ_{IC} denotes the covariance between the interest rate and credit risk of the loan portfolio and σ_{ID} (σ_{CD}) the covariance between the interest rate risk (credit risk) of the loan and the interest rate risk of the deposit portfolio.

When a new deposit Q_D arrives, the overall volume of deposits increases to $D_0 + Q_D$. As attracting deposits equals selling bonds at a mark-up of a, the money market account increases to $M_0 + Q_D(1 + a)$. Under the common assumption that second-order terms of intermediation fees, expected returns and operating cost are negligible,[7] the increase in

[7] i.e. $\left([(1 + r)(1 + a) - (1 + r_D)] Q_D - C(Q_D)\right)^2 = 0$.

expected utility due to a new deposit inflow is:[8]

$$\begin{aligned}\Delta EU\left(W|Q_D\right) =&U'\left(\overline{W}\right)\left[\left[\left(1+r\right)\left(1+a\right)-\left(1+r_D\right)\right]Q_D-C\left(Q_D\right)\right]\\&+\frac{1}{2}U''\left(\overline{W}\right)\left[\sigma_D^2\left(2D_0+Q_D\right)Q_D-\left(\sigma_{ID}+\sigma_{CD}\right)Q_DL_0\right].\end{aligned}\tag{3.5}$$

Similarly, new loan demand Q_L results in an increase in loans' market values to L_0+Q_L, and a decrease of the money market account to $M_0-Q_L\left(1-b\right)$. The resulting increase in expected utility under the same assumptions as before is:

$$\begin{aligned}\Delta EU\left(W|Q_L\right) =&U'\left(\overline{W}\right)\left(\left[\left(1+r_L\right)-\left(1-b\right)\left(1+r\right)\right]Q_L-C\left(Q_L\right)\right)\\&+\frac{1}{2}U''\left[\left(\sigma_I^2+2\sigma_{IC}+\sigma_C^2\right)\left(2L_0+Q_L\right)Q_L-2\left(\sigma_{ID}+\sigma_{CD}\right)Q_LD_0\right].\end{aligned}\tag{3.6}$$

The bank sets loan fees a and deposit fees b to cover unexpected losses from interest rate and credit risk. However, increasing the magnitude of fees demanded will limit the incentives of deposit supply as well as loan demand. Transaction volumes Q_D and Q_L are exogenously determined, but the likelihood of a new transaction occurring will decrease with the magnitude of fees and follows independent Poisson processes with intensity λ:

$$\lambda_D =\alpha_D-\beta_D\times a,\tag{3.7}$$

$$\lambda_L =\alpha_L-\beta_L\times b.\tag{3.8}$$

The bank's objective function, conditional to, at most, a single transaction occurring, is to set optimal intermediation fees so as to maximize its end-of-period expected utility:

$$\max_{a,b} EU\left(\Delta W\right)=\left(\alpha_D-\beta_D\times a\right)\Delta EU\left(W|Q_D\right)+\left(\alpha_L-\beta_L\times b\right)\Delta EU\left(W|Q_L\right).\tag{3.9}$$

Rearranging first-order conditions, the optimal loan fee is

$$\begin{aligned}b^* =&\frac{1}{2}\frac{\alpha_L}{\beta_L}+\frac{1}{2}\frac{C\left(Q_L\right)}{Q_L\left(1+r\right)}-\frac{1}{2}\frac{r_L-r}{\left(1+r\right)}\\&-\frac{1}{4}\frac{U''\left(\overline{W}\right)}{U'\left(\overline{W}\right)}\frac{\left[\left(\sigma_I^2+2\sigma_{IC}+\sigma_C^2\right)\left(2L_0+Q_L\right)-2\left(\sigma_{ID}+\sigma_{CD}\right)D_0\right]}{\left(1+r\right)},\end{aligned}\tag{3.10}$$

[8] Ho and Saunders (1981) and all succeeding models calculate the increase in net wealth to be $a\ Q_D$. However, we choose the intermediation fees to be earned in advance and allow them to earn the risk-free rate (see Freixas and Rochet, 2008, p. 232). The same approach is used for newly demanded loans.

and the optimal deposit fee

$$\begin{aligned} a^* =& \frac{1}{2}\frac{\alpha_D}{\beta_D} + \frac{1}{2}\frac{C\left(Q_D\right)}{Q_D\left(1+r\right)} + \frac{1}{2}\frac{r_D - r}{\left(1+r\right)} \\ & - \frac{1}{4}\frac{U''\left(\overline{W}\right)}{U'\left(\overline{W}\right)}\frac{\left[\sigma_D^2\left(2D_0 + Q_D\right) - 2\left(\sigma_{ID} + \sigma_{CD}\right)L_0\right]}{\left(1+r\right)}. \end{aligned} \tag{3.11}$$

The optimal fees on loans a^*, and deposits b^* both depend on four components: (i) a market power, (ii) an operating cost, (iii) an expected excess holding period return, and (iv) a risk component. Whereas previous models only observed the influence of three components, the influence of the expected excess holding period returns $(r_L - r)$ and $(r_D - r)$, respectively, has been newly derived. This effect as well as the new special structure of the risk component originate from the bank's risk transformation, encompassing maturity transformation, as introduced in our model.

Market power: The competitive structure of the banking industry is determined by the extent to which (the likelihood of) loan demand and deposit supply are inelastic with respect to the intermediation fees charged, represented by the factor β. With an increasing ratio of α/β, elasticity decreases and banks gain market power which translates into higher fees.

Operating cost: The average operating cost incurred per unit of transaction volume, $C\left(Q\right)/Q$, is passed on to lenders and borrowers as in a standard monopolistic setting.

Expected excess holding period returns: In addition to cost, banks also take expected excess holding period returns from risk transformation into account when setting loan and deposit fees, which is a new result derived from our model. With positive expected excess holding period returns over the horizon T, i.e. $(r_L - r > 0)$ and $(r_D - r > 0)$, respectively, loan fees are reduced and deposit fees increased. This means banks are willing to lower loan fees during those times when granting loans is expected to generate positive risk transformation income above the risk-free rate (in the form of the coupon payments of the underlying bond and possible valuation gains). Other things being equal, higher expected excess returns compensate the bank more for risk-taking and allows a lowering of the loan fees demanded from the customer for covering unexpected losses. For deposits, the opposite holds, resulting in increased intermediation fees, as they represent a liability position.

Qualitatively, we observe the same effect for expected excess returns as for operating cost when a monopolistic supplier (demander) determines the profit-maximizing price in the Monti-Klein model of financial intermediation: expected excess holding period returns in loans can be regarded as reductions in marginal cost and the expected profits are passed on to customers in the same way as marginal costs are priced (Freixas and Rochet, 2008, pp. 57-59), and vice versa for deposits.

Risk component: The risk component consists of the product of the bank's absolute risk aversion ($-U''/U'$) and the bank's overall risk exposure from the balance sheet side perspective the transaction is related to. Given positive risk exposure, banks facing higher levels of risk aversion charge higher fees.

Equations (3.11) and (3.10) reveal that fees increase with the total risk exposure of the balance sheet side the initiated transaction belongs to, and decrease with the hedging ability of the opposite balance sheet side. More specifically, loan fees increase with loan's interest (σ_I^2) and credit risk (σ_C^2), as well as their covariance, and the volume of loans affected by such risks after the transaction occurs ($L_0 + Q_L$). However, fees are reduced when deposits hedge loan's risk, i.e. by increasing covariance of the loan's risk and the interest risk inherent in deposits, ($\sigma_{ID} + \sigma_{CD}$), weighted by the volume of deposits D_0. When deposits are being priced, the opposite holds.

Ignoring credit risk, i.e. $\sigma_C^2 = \sigma_{IC} = \sigma_{CD} = 0$, the risk exposure in loan fees behaves very much like a bank's (modified) duration gap. The modified duration gap measures the bank balance sheet's sensitivity to (small) changes in the yield curve by accounting for volume-weighted net effect of interest rate changes on assets' and liabilities' present values. Ceteris paribus, it increases with a higher (shorter) maturity of the loans (deposits). Qualitatively, the same holds for the risk components: We have $\sigma_{ID} = \sigma_I^2$ when loans and deposits have the same maturity; thus, interest rate risk of loans and deposits offset each other in this case, with the exception of volume-effects. When the loan maturity increases, we can expect higher σ_I^2 and a reduced hedging ability of the deposits as the correlation between respective returns tends to decrease with a higher maturity difference. This implies the risk component increases, yielding higher loan fees b^*.

For the risk component in deposit fees analogous considerations hold; however, it is linked to a reverse duration gap as it measures the risk of the deposit portfolio less the hedging ability of the loan portfolio. This implies the deposit fee a^* decreases with an increasing duration gap. The economic rationale is that banks with high IRR from holding long-term loans in their portfolios would be willing to bid more aggressively on deposits by offering more favorable rates.

In sum, loan and deposit fees are determined by the same four components introduced above. Market power, operating cost and the risk component have a positive impact on fees charged. Positive expected excess holding period returns show a positive effect on loan fees and a negative effect on deposit fees, as a result of the opposed positions — long vs. short — of their underlying portfolios.

As previous literature has focussed on the *pure intermediation spread* s^*, defined as the sum of both intermediation fees, i.e. $s^* = a^* + b^*$, its determinants are illustrated below:

$$\begin{aligned} s^* =& \frac{1}{2}\left(\frac{\alpha_L}{\beta_L} + \frac{\alpha_D}{\beta_D}\right) + \frac{1}{2}\left(\frac{C\left(Q_L\right)}{Q_L\left(1+r\right)} + \frac{C\left(Q_D\right)}{Q_D\left(1+r\right)}\right) - \frac{1}{2}\frac{r_L - r_D}{\left(1+r\right)} \\ & - \frac{1}{4}\frac{U''\left(\overline{W}\right)}{U'\left(\overline{W}\right)} \frac{\left[\left(\sigma_I^2 + 2\sigma_{IC} + \sigma_C^2\right)\left(2L_0 + Q_L\right) - 2\left(\sigma_{ID} + \sigma_{CD}\right)\left(D_0 + L_0\right) + \sigma_D^2\left(2D_0 + Q_D\right)\right]}{\left(1+r\right)}. \end{aligned} \tag{3.12}$$

It should be noted that the *pure spread* solely encompasses fees related to transaction uncertainty (Ho and Saunders, 1981) but does not fully represent the net interest income (NIM) in our model. Owing to the different maturities of loans and deposits, the interest payments from the underlying bonds do usually not offset each other but contribute to the NIM as well.

The same four components, found separately in loan and deposit fees, also influence the pure spread. Market power and operating cost are simply the sum of the terms found in loan and deposit fees, and can be interpreted as the bank's overall market power, and operating cost from financial intermediation, respectively. The expected excess holding period returns determining loan and deposit fees (partly) offset each other and translate into $(r_L - r_D)$, the expected holding period return from overall risk transformation. $(r_L - r_D)$ can be expected to take positive values in times of normally-shaped yield curves due to, in general, a positive maturity transformation. Hence, the bank is willing to lower overall fees when it expects positive returns from maturity transformation. The combined risk component rises in both the loan's and the deposit's risks, always weighted by the new business volume after the transaction takes place, $(L_0 + Q_L)$ and $(D_0 + Q_D)$, and is reduced by the covariance hedges times the volume of the total initial interest-bearing business, i.e. $(D_0 + L_0)$.

3.4 Data

3.4.1 The German Banking System

To empirically test the predictions derived from our theoretical model, we utilize a dataset covering the entire German commercial banking sector for a range of ten years between 2000 and 2009.[9] The time span contains substantial variation in the yield curve, with steep and considerably flat term structures following each other.

The German banking system is structured into three pillars where affiliation to a certain pillar is determined by ownership (e.g. Brunner et al., 2004). The three pillars are private commercial banks, state-owned banks and banks of the cooperative sector. The majority of these banks belong to the last two pillars. State-owned savings and cooperative banks operate in geographically delimited areas and there is almost no competition between them across local banking markets. In an international context, they are small to medium-sized with only limited direct access to the capital market. The business models of these banks are very homogeneous and mainly consist of pure intermediation services, as assumed in the model. Net interest income corresponds to the largest fraction of their earnings and income from maturity transformation contributes substantially to this (Memmel, 2011), whereas non-interest fee, and especially trading income are of only limited importance.

[9] Data for 1999 is used to create instruments from first-differenced covariates.

As a general rule, savings and cooperative banks access capital markets not independently, but mainly through the head institutions of their respective interbank networks. The head institutes provide liquidity supply to their affiliated members and allow them to manage their duration gaps through interbank lending. These interbank networks shield the smaller savings and cooperative banks against monetary contractions, without having to reduce lending as a consequence of deposit outflows and drastic balance sheet duration adjustments (Ehrmann and Worms, 2004). The mitigated impact of the monetary transmission channel allows us to investigate interest margins that are only moderately affected by changes in the volume of interest-bearing business.

We investigate the full German universal banking sector, leading to a broad sample of more than 2,000 banks and 16,000 bank years. Such a sample size, though limited to a single country, exceeds most of the international studies on determinants of bank margins conducted so far (e.g. Demirgüç-Kunt and Huizinga (1999); Saunders and Schumacher (2000); Maudos and Fernández de Guevara (2004); Claeys and Vander Vennet (2008) — except for Carbó and Rodríguez (2007) and Nguyen (2012), who have a bigger sample size).

Although only limited data is publicly available, using supervisory data we can utilize detailed information on a bank's lender and borrower characteristics and maturities. The data used in this analysis is based on the following supervisory data collected by the Deutsche Bundesbank: balance sheet figures are taken from year-end values of the monthly balance sheet statistics, cost and revenues from bank's earning statements, and additional bank-specific information stems from the auditor's reports. Macroeconomic and term structure data are those provided to the public on the Deutsche Bundesbank's website. Earlier data cannot be used due to a major change in the reporting structure of the monthly balance sheet statistics in 1998.

A further point that has to be taken into account is the treatment of mergers and the effect thereof on the comparability of pre- and post-merger accounting figures. During the sample period, the German banking sector was affected by a major consolidation wave, resulting in several hundred mergers, most notably among savings and cooperative banks.

In order to account for structural changes in the time series of variables following mergers, a new synthetic bank is created after every merger. Thus, for a single merger between two different banks, three synthetic banks exist: two pre-merger banks and another post-merger one.

To capture differences originating from the institutional characteristics in the banking sector, we initially conduct our analysis on the complete sample, however we subsequently divide it into three sub-samples. Although the three pillars would provide a good pre-specified segmentation, we place the head institutions of the state-owned (mainly Landesbanken) and of the cooperative pillar together with all private commercial banks into a group, from now on referred to as “other banks”. The rationale behind this institutional relocation is the differences between head institutions and their affiliated savings and co-operative banks with regard to size, business model, capital market access, but also IRR management (Ehrmann and Worms, 2004).

3.4.2 Variables

The dependent variables we investigate are (i) the net interest margin (NIM), (ii) the interest income margin (IIM), and (iii) the interest expense margin (IEM), where total assets, interest-earning assets, and interest-paying liabilities, respectively, have been chosen as denominators. If the denominator of explanatory variables is adjusted in line with the dependent variable being investigated this will be displayed as “total (interest-bearing) assets (liabilities)” in the following analysis.

It should be noted that these dependent variables are not equivalent to the (optimal) loan and deposits fees from the theoretical model, but encompass them. The interest income and expenses from new loan and deposit transactions observed at the end of the period are the par yield coupon payment of a risky long-term corporate bond plus the loan fees, and the par yield coupon payment of a shorter-term default-free government bond less the deposit fee, respectively.

This generates two implications for our empirical design. First, we need to control for coupon payments of fairly-priced capital market bonds as they are included in the dependent variables by construction. We will do this via so-called "revolving portfolios" of bonds, mimicking the maturity structure of the bank. Second, interest expenses and the deposit fees a^* derived from the model are negatively linked. Hence, empirical proxies for deposit fee determinants should exhibit the opposite of the theoretically derived impact.[10]

The following sub-sections describe the variables proxying for the determinants derived from the model, additional bank-specific and macroeconomic control variables, and the construction of the revolving portfolios. Table 3.1 provides an overview of the explanatory variables included in the regression analysis, their expected impact on the three bank margins and the usage in previous studies investigating bank margins.

3.4.2.1 Model-derived Variables

Market power: We include *Lerner indices* to capture banks' ability to exercise market power from facing inelastic demand for loans and supply of deposits. As the model implies a positive influence of market power on loan and deposit margins b^* and a^*, we expect a positive influence of the Lerner indices on IIM and NIM, and a negative influence on IEM.

The Lerner index measures banks' ability to set mark-ups over the marginal cost mc necessary to provide a service in relation to the price p charged, i.e. $(p - mc)/p$. To estimate a bank's overall market power, we estimate a single-output translog cost function dependent on three input factors (see e.g. Maudos and Fernández de Guevara, 2004; Maudos and Solís, 2009). Total assets are specified to proxy for output level. Input prices for personnel, physical and financial costs are included. Taking interest-paying liabilities as an input rather than an output is consistent with the intermediation approach of banking (Sealey and Lindley, 1977). The output price p is exogenously determined and

[10] However, for better interpretability we will employ modified duration gaps, instead of reverse modified duration gaps.

Table 3.1: Variable Description

Variable	Proxy	Pred. coeff. (IIM|IEM|NIM)	Use in other studies
Model-derived variables			
Market power	Lerner index: $(p-mc)/p$, where total market power is calculated using total assets as an output with a three factor translog cost function. Loan and deposit market power, however, have been jointly estimated using total interest-bearing assets and liabilities, respectively, as output proxies and a two input factor translog cost function, excluding financial cost (of deposits) as in Maudos and Fernández de Guevara (2007)	(+|-|+)	Maudos and Fernández de Guevara (2004); Maudos and Solís (2009)
Operating cost	Operating expenses / total (interest-bearing) assets (liabilities)	(+|-|+)	Maudos and Fernández de Guevara (2004); Maudos and Solís (2009)
Expected excess holding period return	Term spread: the difference between the duration implied par yield and the 6-month par yield, or between asset and liability duration-implied par yields for the NIM	(-|-|-)	Not used up to now
Risk aversion	Excess capital: (Regulatory capital - 0.08 × risk-weighted assets) / total assets	(+|-|+)	Excess capital has not been used up to now, but was proposed by Maudos and Solís (2009). Previous studies used capital ratios, i.e. (regulatory) capital / total assets (McShane and Sharpe, 1985; Angbazo, 1997; Maudos and Fernández de Guevara, 2004; Carbó and Rodríguez, 2007; Maudos and Solís, 2009)
Bank-specific IRR exposure	Duration gap: asset duration - liability duration × interest-paying liabilities / interest-earning assets	(+|+|+)	Not used up to now; the most similar interest rate risk measure is the net position of balance sheet items with a repricing period of less than one year in relation to total assets (Angbazo, 1997)
Interest rate volatility	LIBOR volatility: annual standard deviation of the weekly observed 6-month LIBOR rate	(+|+|+)	Different interest rate volatilities have been used to proxy for interest rate risk when explaining NIMs (Maudos and Fernández de Guevara, 2004; Lepetit et al., 2008; Maudos and Solís, 2009). However, these studies were based on models with a single IRR source and could therefore derive predictions for coefficients.
Credit risk	Risk-weighted assets / total assets	(+|nu|+)	Not used up to now
Credit-interest covariance	Annual correlation coefficient between the 5-year government par yield and the 5-year credit spread on corporate bonds over the 5-year government par yield	(?|+|?)	Not used up to now
Bank-specific variables			
Non-interest income (NII)	net fee income / total (interest-bearing) assets (liabilities)	(-|+|-)	Lepetit et al. (2008); Maudos and Solís (2009)
Implicit interest payments (IIP)	(non-interest expenses - non-interest income) / total (interest-bearing) assets (liabilities)	(+|-|+)	Ho and Saunders (1981); Angbazo (1997); Saunders and Schumacher (2000); Maudos and Fernández de Guevara (2004); Maudos and Solís (2009)
Opportunity cost of reserves (OCR)	(cash + deposits with central banks) / total (interest-bearing) assets (liabilities)	(?|+|-)	
Macroeconomic variables			
GDP growth	annual real GDP growth rate	(?|?|?)	Carbó and Rodríguez (2007); Claeys and Vander Vennet (2008); Albertazzi and Gambacorta (2009); Maudos and Solís (2009)
Inflation rate	annual growth rate of consumer price index	(?|?|?)	Demirgüç-Kunt and Huizinga (1999); Claeys and Vander Vennet (2008); Maudos and Solís (2009)
Revolving portfolios	Balance sheet proportion of several lender (borrower) clienteles and maturity brackets × the moving average of par yield government bonds	(+|+|nu)	Memmel (2008) explains interest income and expense margins with revolving tracking bank portfolios

Total (interest-bearing) assets (liabilities) indicates that the denominator of an explanatory variable is total interest-bearing assets if the dependent variable is IIM, total interest-bearing liabilities in case of IEM, and total assets for NIM. The following symbols were used for predicted coefficients, where the following order within brackets is given (IIM, IEM, NIM). (+) denotes an expected positive coefficient, (-) a negative coefficient, (?) that the effect cannot be predicted a priori, and (nu) that the given variable has not been included in a regression on the specific margin.

proxied as interest income in relation to interest-earning assets, and therefore identical to the IIM. Equity is included as a netput. Appendix A provides further technical details.

To derive separate market power estimates for loan and deposit markets from aggregated balance sheet and income data, we follow Maudos and Fernández de Guevara's (2007) approach, and specify a two-output translog cost function. This approach is based on the Monti-Klein model of financial intermediation (Freixas and Rochet, 2008, pp. 57-59) and treats deposits as an output rather than an input. Interest-earning assets proxy for loans, and interest-paying liabilities for deposits, with the ratios of interest income / interest-earning assets (IIM), and interest expenses / interest-paying liabilities (IEM) providing the exogenously determined two output prices. With liabilities being treated as outputs, only personnel and physical costs contribute to input prices.

Operating cost: Following Maudos and Fernández de Guevara (2004), and Maudos and Solís (2009), we proxy the operating cost of financial intermediation using *total operating expenses / total (interest-bearing) assets (liabilities).* However, it should be noted that banks' operating expenses are likely to also include costs that are due to inefficiency and those not related to activities of financial intermediation. Operating expenses are expected to have a positive influence on intermediation fees and, thus, a positive (negative) influence on IIM and NIM (IEM).

Expected excess holding period returns: Theoretically derived expected excess holding period returns cover returns from total risk transformation. However, in line with previous research, we neglect expected returns from credit risk and focus on excess holding period returns in "default-free" government bonds. Fama and French (1989) and Ilmanen (1995) provide empirical evidence that the *term spread* proxies expected excess holding period returns.[11] Therefore, Equations (3.11) and (3.10) imply that loan fees a^* are reduced, and deposit fees b^* are increased when term spreads increase. This translates into expected negative effects on all three bank margins to be examined.

[11] See Campbell and Ammer (1993) for a theoretical justification. Alternative approaches document the power of current forward rates (Fama and Bliss, 1987), or linear combinations of forward rates (Cochrane and Piazzesi, 2005) to forecast future excess returns.

As different banks have different maturity transformation characteristics and thus different expected excess holding period returns in their assets and liabilities, we do not use the same term spread for all banks, but calculate *bank-specific term spreads*. For example, given an upward-sloping yield curve, banks with higher average loan maturity should have higher expected excess holding period returns $r_L - r$. To capture this effect, we calculate the duration of the interest-bearing assets and the par yield of government bonds with a maturity equaling this duration. The bank-specific term spread for the assets, proxying $r_L - r$, is then defined as the difference between this duration-implied par yield and the 6-month par yield. The liability term spread is calculated analogously and the asset-liability term spread, proxying $r_L - r_D$, is the difference between the duration-implied asset and liability par yields. The calculation of assets' and liabilities' durations is analogous to the calculation of the modified duration, described in Appendix B.

Risk component: The composite impact of the risk component will be separated into the influence of distinct variables for our empirical analysis: risk aversion, interest and credit risk.

Risk component — Risk aversion: Most previous studies include capital ratios as proxies for risk aversion (McShane and Sharpe, 1985; Maudos and Fernández de Guevara, 2004; Maudos and Solís, 2009), or, without directly referring to risk aversion, as measures of insolvency risk (Angbazo, 1997; Carbó and Rodríguez, 2007). As capital ratios do not account for differing risk levels, a point already stressed by Gambacorta and Mistrulli (2004), *capital in excess of minimum regulatory requirements / total assets*, or in short *excess capital*, generally seems a more adequate proxy for risk aversion. In our model, excess capital should be related to higher IIM and NIM, and lower IEM. However, empirical studies using capital ratios to investigate the NIM found mixed results, with both significantly positive as well as negative effects.

Risk component — Interest rate risk: As already discussed in Section 3.3, the second factor in the risk component behaves very much like a (reverse) modified duration gap. Using the detailed information on volumes and maturities of different lender and borrower types, we calculate the modified durations of the assets and liabilities, D^A_{mod} and D^L_{mod}, respectively; then, the modified *duration gap* D_{gap} is defined as:[12]

$$D_{gap} = D^A_{mod} - D^L_{mod} \frac{\textit{total interest-earning liabilities}}{\textit{total interest-paying assets}}. \tag{3.13}$$

Details can be taken from Appendix B. We use the modified duration gap as an independent variable for all three margins for better comparability rather than using a reverse modified duration gap in the case of IEM. Based on our model, we expect a positive influence on all three margins.

Whereas the modified duration gap measures the overall sensitivity of a bank's net portfolio value to changes in the yield curve, it does not capture the interest rate volatility that determines the probability of changes in the yield curve. For multicollinearity reasons, we do not include separate volatility measures for loans and deposits, σ_I and σ_D. Instead, we include just one: the annual *volatility of weekly 6-month LIBOR rates* — measured over a 52-week window — to proxy for the risk of unexpected changes in the yield curve. It should be noted that previous studies, based on models with the assumption of equal loan and deposit maturity, modeled IRR only as the volatility of specific interest rates (Ho and Saunders, 1981; Saunders and Schumacher, 2000; Maudos and Fernández de Guevara, 2004; Maudos and Solís, 2009). The model implies all three margins increase with higher volatility.

Risk component — Credit risk: The credit risk associated with financial intermediation is integrated into the regression analysis using *risk-weighted assets to total assets*. Whereas for the other banks risk-weighted assets are likely to be also associated with off-balance sheet activities and market risk, they are mainly determined by the default risk of loan and bond portfolios for many savings and cooperative banks. With deposits assumed to be default-free, the proxy is only used in regressions explaining IIM and NIM, and expected to have a positive impact.

[12] Angbazo (1997) uses the one-year repricing gap, defined as the difference between assets and liabilities with a repricing frequency of less than one year to total assets (first used by Flannery and James, 1984). In our analysis we prefer to use more detailed information on the maturities of assets and liabilities as one-year repricing gaps will capture the majority of liquidity and refinancing interest risk, but only partly the valuation risk when long-term securities are affected by interest rate changes.

Risk component — Credit-interest risk covariance: To proxy for the covariance between credit and interest rates we include the *correlation coefficient between the 5-year government par yield and the default spread* of a weighted index of corporate bonds over the 5-year government par yield. The correlation is calculated annually on the basis of weekly rates. Whereas the IIM and the NIM are determined by both the correlation of loan as well as deposit returns with the credit spread, the IEM is only determined by σ^2_{CD}. Therefore, the expected coefficient sign can only be predicted for the IEM and can be expected to increase the expenses paid by the bank.

3.4.2.2 Control Variables

Previous studies investigating bank interest margins include a number of additional control variables not predicted by the model to influence the pure spread of intermediation, but to also have an impact on observed bank margins. Following these studies, we include three additional bank-specific, as well as two macroeconomic variables. Furthermore, we control for coupon payments of fairly-priced capital market bonds as they are included in the dependent variables.

Non-interest income (NII): Past developments in banking are described as disintermediation with a change from traditional financial intermediation to other banking activities in order to compensate for declining profitability. Carbó and Rodríguez's (2007) model investigates the cross-selling behavior between loans and non-traditional activities, which have been proxied using *non-interest net fee income to total (interest-bearing) assets (liabilities)* (Lepetit et al., 2008).[13] Cross-selling assumes that banks are willing to forego traditional interest-generating income for non-interest income (NII). Hence, the higher the *non-interest income to total assets*, the lower the corresponding fees charged, resulting in decreasing IIM and NIM, and increasing IEM.

Implicit interest payments (IIP): We also include a proxy for implicit interest payments (IIP) using *(non-interest expenses less non-interest income) / total (interest-bearing)*

[13] In contrast to Lepetit et al. (2008), we do not additionally include trading activities as many smaller German banks to not generate any such income.

assets (liabilities) that aims to reflect the cost of additional services for which customers have not been charged. Initially included to capture competition in the market for deposits (Ho and Saunders, 1981), it is expected to result in lower interest expenses and a negative coefficient on the related margin and a positive one on NIM. However, additional services might also be present for loans, and a positive effect on the IIM might also be observed.

Opportunity cost of holding reserves (OCR): Finally, the opportunity cost of holding reserves (OCR) originates in asset portfolios that pay no, or in the case of central bank deposits in Germany, only below market rates. We include *cash and deposits with central banks to total (interest-bearing) assets (liabilities)* to proxy for OCR. As these reserves implicitly increase the cost of funding by foregone interest income, they are likely to be priced into deposit rates. A higher ratio of cash and deposits with central banks can therefore be expected to lead to lower interest expenses and ultimately higher net interest incomes; however, the effect on interest income margins remains unclear a priori.

Macroeconomic variables: Two macroeconomic variables are included: the annual real *GDP growth* rate controls for demand (for loans) and supply (of deposits) effects in bank profitability, and the *inflation rate* integrates effects of nominal contracting. For both variables, positive as well as negative coefficients have been observed when investigating bank NIMs (Demirgüç-Kunt and Huizinga, 1999; Claeys and Vander Vennet, 2008; Albertazzi and Gambacorta, 2009) depending on the banking sample and time period observed, so no a priori assumption of the coefficient sign derived will be given.

Revolving portfolios: As already discussed at the beginning of Section 3.4.2 we have to control for fair coupon payments from the underlying bonds, captured in the dependent variables, to separate the effects of the fee determinants our model predicts. Since today's interest income and expenses depend on both volume and current as well as former fair market rates for different maturities — depending on the points in time current on-balance positions have been conducted — we build revolving portfolios of bonds with different maturities initiated at different points in time. Since credit risk premia are controlled for by the credit risk variable we consider default-free government bonds.

We make use of the Deutsche Bundesbank's monthly balance sheet statistics which report volumes for different lender and borrower clienteles in time brackets according to the initial time to maturity, as shown in Table B.1. The strategy of revolving portfolios basically consists in revolvingly investing into par-yield government bonds whose initial maturity depends on the respective balance sheet position's maturity bracket. We assume initial maturity is equally distributed within each bracket, each bond pays par-yield when initiated, and maturing bonds are replaced by new bonds of the same maturity. The resulting coupon payments represent weighted moving averages of par-yields as shown by Memmel (2008). They are calculated for each position and time bracket and are — divided by interest-paying assets, interest-paying liabilities, or total asset, respectively — used as control variables when investigating NIM, IIM, and IEM.[14] Memmel (2008) provides empirical evidence that this approach explains much of the time series and cross-sectional variation of banks' interest income and expense margins. Further details can be taken from Appendix C.

3.4.3 Summary Statistics

We employ a dataset of the entire German commercial banking sector, but exclude synthetic banks if (i) they have missing values for one of the above-stated variables; (ii) showed negative values for any balance sheet position that could not be negative. For estimating non-negative marginal cost in translog cost functions we additionally completely excluded synthetic banks whose (iii) input prices differed by more than 2.25 times the standard deviation in a given year, and (iv) whose assets are below EUR 25 million. This leaves us with a total sample of 2,380 (synthetic) banks, 594 of which are savings, 1,730

[14] As the reported maturity brackets for assets and liabilities do not have matching maturities, we cannot create net revolving portfolios for every single bracket — used in explaining income and expenses — when analyzing the net interest margin. Therefore, in this case we create three net product group revolving portfolios by combining revolving portfolios for bank, non-bank, and bond lending and then subtracting those for borrowing. Savings accounts are added to non-bank borrowing and subordinated debt to bonds issued.

cooperative, and 56 so called other, mainly private commercial banks. Table 3.2 provides summary statistics for the overall sample and the sub-samples.

There are some noteworthy features in the data, especially highlighting differences between the sub-samples of savings and cooperative banks, and the remaining banks in the other bank sample. Average total assets are EUR 1,018 million, but range from EUR 395 million for cooperative banks to EUR 9,077 million for other banks. The overall sample median, however, is only EUR 329 million, serving as evidence that a huge number of small banks operate in the German banking system, whereas averages are driven by a small number of large institutions. Savings and cooperative banks samples are comparatively homogeneous with respect to size, whereas the other bank sample is much more heterogeneous. Duration gaps are higher for savings and cooperative banks, which have interest sensitivities of 0.84 and 0.9, respectively, compared with other banks with only 0.64. Net interest income margins range from 2.03% for savings, and 2.48% for cooperative to 2.58% observed for other banks. However, the standard deviation of NIM is more than three times as high for other banks as for cooperatives. The smaller savings and cooperative banks rely to a larger extent on savings deposit funding, which corresponds to 32.6% and 33.7%, respectively, of total assets, whereas other banks show a quota of only 16.9%. Revisiting that half of the savings deposit are considered to be long-term core deposits, it is striking that savings and cooperative banks still have substantially larger duration gaps.

As other banks have the highest net interest income despite the fact that they are less heavily involved in maturity transformation, they seem to earn major parts of their interest income through credit risk premia. And indeed, other banks have higher credit risk ratios of RWA to total assets: 63.2% compared to 55.3% and 60.2% for savings and cooperative banks, respectively.

Table 3.2: Summary Statistics

	Full sample			Savings banks		Cooperative banks		Other banks	
	Mean	Std. dev.	Median	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Bank size (denominators)in €million									
Total interest-earning assets	898.189	5,685.103	290.764	1,767.913	2,488.304	350.088	559.547	8,125.128	35,179.374
Total interest-paying liabilities	906.510	5,419.367	295.307	1,822.069	2,543.179	355.553	593.923	7,714.408	33,341.790
Total assets (TA)	1,017.514	6,585.622	328.581	2,019.671	2,814.181	394.656	653.023	9,077.482	40,872.249
Bank interest margins									
Interest income margin (IIM)	5.509	0.676	5.495	5.467	0.610	5.519	0.634	5.648	1.752
Interest expense margin (IEM)	2.859	0.557	2.841	3.022	0.542	2.795	0.540	3.034	0.796
Net interest margin (NIM)	2.360	0.530	2.377	2.027	0.394	2.473	0.450	2.582	1.554
Model-derived variables									
Market power (loans)	49.345	16.165	48.411	51.487	15.945	48.680	16.057	46.121	19.299
Market power (deposits)	-23.625	36.854	-19.333	-24.484	34.023	-23.152	37.734	-28.654	39.037
Market power (overall)	37.006	8.830	37.733	37.879	7.801	36.766	8.799	34.729	16.424
Operating cost	2.222	0.555	2.182	1.828	0.254	2.354	0.518	2.544	1.368
Term spread (asset)	0.611	0.429	0.602	0.621	0.429	0.607	0.428	0.603	0.477
Term spread (liability)	0.543	0.410	0.516	0.577	0.382	0.529	0.413	0.576	0.561
Term spread (asset-liability)	0.068	0.439	0.083	0.044	0.399	0.078	0.440	0.027	0.709
Risk aversion	3.203	1.833	2.844	2.769	1.475	3.361	1.856	3.155	3.324
Modified asset duration	2.429	0.246	2.466	2.559	0.154	2.405	0.208	1.737	0.559
Modified liability duration	1.540	0.223	1.566	1.651	0.188	1.512	0.201	1.169	0.428
Duration gap	0.877	0.274	0.867	0.841	0.241	0.897	0.268	0.639	0.538
LIBOR volatility	0.343	0.161	0.321						
Credit risk	59.016	11.520	60.039	55.258	11.197	60.233	11.073	63.174	17.507
Credit-interest covariance (correlation)	-11.488	12.202	-4.879						
Non-interest income (NII)	0.667	0.260	0.636	0.556	0.111	0.698	0.239	0.951	0.878
Implicit interest payments (IIP)	1.338	0.447	1.310	1.102	0.237	1.431	0.438	1.101	1.055
Opportunity cost of reserves (OCR)	0.898	0.392	0.858	0.744	0.284	0.969	0.393	0.426	0.528
Macroeconomic variables									
GDP growth	0.954	2.124	1.208						
Inflation rate	1.554	0.695	1.763						
Balance sheet compositions									
Loans to banks	11.670	7.581	10.228	8.333	5.987	12.649	7.338	18.469	14.480
Loans to non-banks	60.042	11.825	61.555	59.541	12.024	60.253	11.314	59.095	21.144
Bonds held	17.866	9.577	16.497	19.092	10.206	17.519	9.022	14.987	15.600
Loans from banks	15.429	8.081	14.203	21.007	8.994	13.382	6.099	16.640	16.814
Loans from non-banks	38.213	9.885	37.217	32.438	7.762	39.875	9.163	51.004	17.832
Saving deposits	33.025	9.761	33.139	32.591	8.190	33.704	9.612	16.926	14.848
Subordinated debt	0.531	0.964	0.000	1.317	1.395	0.249	0.520	0.524	0.814
Bonds issued	2.714	3.706	0.846	2.755	3.030	2.719	3.896	2.113	4.413

For explanatory variables calculated as quotas to total (interest-bearing) assets (liabilities), total assets have been chosen for the summary statistics above. Balance sheet compositions are quotas in relation to total interest-bearing assets, or liabilities, respectively, and were used to calculate revolving portfolios by multiplying year-end values with moving averages of government par yields. All variables are displayed in percentage terms, except for the size variables used as denominators, which are denoted in €million, and the duration measures. Modified asset and liability durations are not used as explanatory variables independently, but were used to calculate the duration gap, and "duration-implied" term spreads.

3.5 Empirical Analysis

3.5.1 Econometric Model

Previous studies mainly focused on an investigation of the net interest margin (NIM) as a widely used measure of commercial banks' core business profitability.[15] Empirical findings have been compared to the theoretical determinants derived for the pure spread. As Ho-Saunders-type models derive determinants for loan and deposit fees independently, we can test the related hypotheses for loans and deposits separately. We are the first to additionally examine the influence of the model-derived factors on the interest income margin (IIM) and the interest expense margin (IEM) separately. The reduced form regression equation of the model is given by:

$$BM_{it} = \alpha_i + \sum_{j=1}^{J} \beta^j TM_{it}^j + \sum_{k=1}^{K} \gamma^k BS_{it}^k + \sum_{l=1}^{L} \delta^l ME_t^l + \sum_{m=1}^{M} \eta^m RP_{it}^m + \varepsilon_{it} \tag{3.14}$$

for $t = 1, ..., T$, indicating the time period, and $i = 1, ..., N$ as the number of banks in the sample.[16] BM is the bank margin examined and will be one of the three bank margins introduced. TM refers to the vector of variables determined by the theoretical model. BS is a vector of additional bank-specific control variables that are likely to influence empirically observed bank margins, but are not part of our model. ME represents macroeconomic variables with a common influence on bank margins. Finally, RP represents the vector of revolving portfolios.

All regressions are estimated using fixed effects two-stage least squares (2-SLS) instrumental variables (IV) techniques. As output prices for Lerner indices (and in the case of

[15] Exemptions are, e.g. Carbó and Rodríguez (2007), who use a wider definition of bank margins and also include New Empirical Industrial Organizations margins, and Lepetit et al. (2008), who investigate several different definitions of bank spreads.

[16] Ho and Saunders (1981) and Saunders and Schumacher (2000) estimate the model in a two-step procedure that aims to derive the pure spread from the first-step regressions. The pure spread is considered to be the intercept from a regression of the NIM on all factors not explicitly derived from the model. Focusing on interest risk, in our setting we prefer the single-step approach as it allows the revolving portfolios and the variables proxying for the interest risk in the intermediation fees to be correlated.

overall market power indices, also the input price of financial cost) were estimated on the basis of those variables that they should now explain, we instrument Lerner indices with their own first difference. Furthermore, non-interest income (NII) might be endogenous for reasons of reversed causality, when banks are willing to grant more favorable interest conditions in order to stimulate the cross-selling of fee-generating business (Maudos and Solís, 2009). As Anderson-Rubin F-tests reject the hypothesis of NII being exogenous, we also instrument it with its own first difference. We investigate the relevance of the instruments, testing for underidentification (Kleibergen and Paap, 2006) and weak identification based on the Cragg-Donald F-statistic. Tests for underidentification can be rejected for all samples and all margins at convenient levels. The test statistic for weak identification is calculated for clustered standard errors and based on the rank test of Kleibergen and Paap. The critical value of the Stock and Yogo (2005) weak instrument size test with two exactly identified endogenous regressors based on heteroskedastic Cragg-Donald statistic is 7.03. All samples except for the other bank sample, which has by far lower sample size, reject the weak instrument hypothesis. For the NIM and the IIM, the test statistics for the complete sample statistics display always the highest value, indicating that the low statistics for the other bank sample are driven by sample size. Results are displayed for all samples, both as coefficients from level-on-level regressions and as elasticities. The coefficients for elasticities have been multiplied by the factor 10 for better visibility.

3.5.2 Net Interest Margin

First, in line with most of the previous literature we investigate the net interest margin and display our results in Table 3.3. Our interest is focused on the explanatory variables determining the pure intermediation spread (3.12) in our theoretical model, namely the bank's market power, operating costs, expected excess holding period returns, risk aversion, interest rate risk and credit risk, and the correlation between these two risks.

The Lerner indices as a proxy for market power are highly significant and have a strong impact: An increase by 10% leads to an increase in the net interest margin by nearly 11%. This effect is especially pronounced for savings banks (increase in the NIM by

Table 3.3: Determinants of Net Interest Margin (NIM)

	Total sample (i)		Savings banks (ii)		Cooperative banks (iii)		Other banks (iv)	
	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.
Model-determined variables								
Lerner index (overall)	0.070***	10.932	0.075***	14.076	0.076***	11.280	0.056***	7.599
	(0.0041)		(0.0063)		(0.0047)		(0.0141)	
Operating cost	1.391***	13.223	1.727***	15.769	1.618***	15.560	0.758***	7.393
	(0.1073)		(0.1845)		(0.1009)		(0.2648)	
Term spread (asset-liability)	-0.041***	-0.011	-0.046***	-0.010	-0.046***	-0.014	-0.057	-0.002
	(0.0064)		(0.0115)		(0.0070)		(0.0437)	
Excess capital	0.046***	0.663	0.098***	1.410	0.041***	0.594	0.036*	0.438
	(0.0051)		(0.0126)		(0.0047)		(0.0200)	
Duration gap	0.180***	0.699	0.284***	1.215	0.201***	0.766	0.034	0.085
	(0.0214)		(0.0470)		(0.0276)		(0.1449)	
LIBOR volatility	1.014***	1.520	1.168***	2.040	1.080***	1.542	0.861***	1.168
	(0.0712)		(0.1238)		(0.0770)		(0.2323)	
Credit risk	0.007***	1.772	0.007***	1.862	0.007***	1.783	0.005	1.315
	(0.0006)		(0.0014)		(0.0007)		(0.0039)	
Credit-interest covariance	0.028***	1.021	0.030***	1.302	0.032***	1.119	0.019***	0.636
	(0.0021)		(0.0030)		(0.0024)		(0.0068)	
Bank-specific variables								
NII	-1.357***	-3.889	-3.347***	-9.392	-1.548***	-4.427	-0.430	-1.557
	(0.1505)		(0.4140)		(0.1252)		(0.3414)	
IIP	-0.458***	-2.603	-0.585***	-3.194	-0.623***	-3.614	-0.027	-0.118
	(0.0639)		(0.1161)		(0.0606)		(0.1491)	
OCR	0.003	0.013	-0.010	-0.038	0.019	0.076	-0.037	-0.058
	(0.0103)		(0.0248)		(0.0129)		(0.1442)	
Macroeconomic variables								
GDP growth	-0.118***	-0.478	-0.091***	-0.421	-0.154***	-0.595	-0.066**	-0.257
	(0.0106)		(0.0109)		(0.0133)		(0.0267)	
Inflation rate	0.620***	4.368	0.654***	5.364	0.723***	4.850	0.456***	2.879
	(0.0478)		(0.0686)		(0.0552)		(0.1496)	
Revolving portfolios								
Net loans to / from banks	0.007	0.008	0.133***	0.393	-0.078**	-0.037	0.110	0.022
	(0.0295)		(0.0348)		(0.0343)		(0.0955)	
Net business to / from non-banks	-0.044**	-0.008	0.047**	0.057	-0.123***	-0.074	0.120*	0.121
	(0.0204)		(0.0204)		(0.0267)		(0.0658)	
Net bond portfolios	-0.127***	-0.380	-0.219***	-0.849	-0.175***	-0.481	-0.025	-0.056
	(0.0377)		(0.0603)		(0.0414)		(0.1201)	
Obs.	16,396		4,479		11,524		393	
Number of synthetic banks	2,380		594		1,730		56	
GR^2	0.536		0.459		0.592		0.382	
Underid. LM stat. [p-val]	71.18	[0]	40.48	[0]	52.91	[0]	7.459	[0.006]
Cragg-Donald F-test	58.23		30.28		43.55		5.405	

Dependent variable: net interest margin (NIM). Operating cost, non-interest income (NII), opportunity cost of reserves (OCR) and implicit interest payments (IIP) are in relation to total assets. All models have been estimated using fixed effects 2-SLS IV regressions, where Lerner index (overall) and NII have been instrumented with their own first differences. Underid. gives the LM statistic and the p-value for the Kleibergen and Paap (2006) rank test of underidentification. Cragg-Donald F-test gives the Cragg-Donald statistic based on Kleibergen and Paap's rank of the matrix. Elasticities of variables are displayed on the right next to coefficients and have been calculated at sample mean and multiplied by the factor 10. Elasticities have been estimated using chain rules, and have been multiplied by -10 if evaluated at a negative sample mean. Standard errors are given in parentheses and are clustered at bank level. Significance at the 10%/5%/1%-level is marked by */**/***. GR^2 is the generalized R^2 criterion of Pesaran and Smith (1994) for 2-SLS IV estimation.

14%) and significant for all sub-samples. The higher impact of market power on the NIM underlines the fact that many rural savings and cooperative banks only face competition from a single bank of the other pillar as these banks operate in delimited areas and have only a few branches of private commercial banks in their area, allowing them to charge higher fees.

The operating costs are highly significant as well. The positive sign of the coefficients is in line with the model predictions and the magnitude of the coefficients is economically relevant: an increase by 100 basis points in operating costs translates into an increase of 139 basis points in the NIM, for savings banks the increase amounts as much as to 173 basis points.

Regarding the term spread included as an instrument for expected returns from maturity transformation, we find the expected negative coefficients. The coefficient is significant for savings and cooperative banks, though it is even larger for other banks. From an economic point of view the results confirm that banks pass part of the expected holding period returns on to customers during times when an increasing yield curve, controlled for with revolving portfolios, generates earnings from maturity transformation. However, this effect is economically not very relevant: about a 4 to 6 basis points reduction in fees for a 100 basis points change in the term spread.

In a similar vein, the interest risk proxies also have to be interpreted as additional net fee income. In line with our expectations, we find that savings and cooperative banks earn significant extra charges of 28 and 20 basis points for each additional percentage point of interest sensitivity due to a positive maturity gap. Other banks, in contrast, have a coefficient close to zero, so that a significant impact can be rejected for more than solely small sample size. Similar results are reported for U.S. banks by Angbazo (1997) who finds the one-year repricing gap to be related exclusively to smaller regional banks' NIMs, but not to larger money centered banks. During the period from 2005 to 2009, Memmel (2011) estimates the income generated from maturity transformation to be around 30 basis points for savings and cooperative banks, and 7 basis points for other banks. Hence, the risk premia charged in fees are of a similar magnitude and supplement these earnings.

LIBOR volatility, proxying the macroeconomic risk of unexpected changes in the yield curve, is priced significantly in all banking samples and confirms the results of previous studies investigating banks' NIM. Fees charged are about 100 basis points per percentage point of realized volatility, and are the highest for savings banks.

Credit risk is priced with lower magnitude, but is not significant for other banks, though the inference might suffer from the overly small sample size here. Given positive risk components, as found by the positive coefficients described above, we find positive effects of excess capital for all the samples investigated. The impact of the correlation between interest and credit risk is positive, but only of limited economic magnitude.

Summarizing the results for the net intermediation fee income, we find that our model predictions hold. Fees are (somewhat) reduced when positive returns form maturity transformation are expected. Macroeconomic and microeconomic interest rate risk, i.e. LIBOR volatility and bank-specific duration gap, are priced. Whereas all this holds for the total sample as well as for savings and cooperative banks, we sometimes find a lack of significance for other banks which may be due to the overly small sample size in some cases. However, whereas the LIBOR volatility has a clear impact for other banks, the impact of duration gap is insignificant and the coefficient very small. Given that other banks include (large) private commercial banks whose business is less traditional, and which have better access to capital markets and are, thus, more likely to manage their smaller duration gap via derivatives rather than on-balance, this result seems plausible.

3.5.3 Separation of Interest Income and Interest Expenses

In this section, we separately run the regressions for the interest income margin (IIM, see Table 3.4) and the interest expense margin (IEM, see Table 3.5). Controlling for fair coupon payments from the underlying bonds via revolving portfolios makes it possible, based on Equations (3.10) and (3.11), to test the model-derived hypotheses for the loan and deposit fee separately. This analysis also reveals which balance sheet side, loans or deposits, drives the results discovered for the NIM in Section 3.5.2. When we run the separate regressions, the share of explained variation (the generalized R^2) increases —

compared to the regression for the net interest margin — from around 0.54 to 0.87 in both cases.

Lerner indices are significant for both interest income and interest expenses, indicating that banks can exploit their market power by increasing intermediation fees on both the asset and the liability side, as predicted by our model. Comparing the magnitude of the coefficients and elasticities, the results imply that market power has a much greater impact on the asset than on the liability side.

By contrast, operating costs seem to be solely priced on the liability side. Whereas the coefficients are insignificant or, at most, weakly significant on the asset side, we find highly significant coefficients (except for the sub-sample of other banks) on the liability side.

The term spread, as an indicator of in how far banks price expected excess holding period returns, reveals the expected negative coefficient on the asset side, and here the effect is even bigger than the one observed for the net interest income. Banks are willing to lower loan fees by 9 to 17 basis points for a 100 basis point steepness in the yield curve. For liabilities, contrary to the model predictions, we find positive coefficients, though only significant for the sub-sample of cooperative banks. Moreover, the size of the coefficients (0.01 to 0.02) and elasticities (0.002 to 0.004) are economically negligible.

Similar effects can be observed for the pricing of on-balance interest rate risk measured by the duration gap. For the asset side, we find the expected positive and significant (except for other banks) coefficients (0.37 and 0.57 for savings and cooperative banks, respectively). This implies banks charge extra intermediation fees when a long-term loan exposes them to interest rate risk from maturity transformation. This fee also increases with the risk of unexpected changes in the yield curve, measured by LIBOR volatility, with coefficients ranging from 0.93 to 1.67. For the liability side, the duration gap also has positive coefficients (0.005 to 0.08) but they are only significant for cooperative banks. The LIBOR volatility has a positive and significant (except for other banks) impact on fees as well; however, these volatility coefficients and elasticities are much smaller than those for the asset side.

Table 3.4: Determinants of Interest Income Margin (IIM)

	Total sample (i)		Savings banks (ii)		Cooperative banks (iii)		Other banks (iv)	
	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.
Model-determined variables								
Lerner index (assets)	0.051***	4.680	0.044***	4.204	0.056***	5.042	0.065***	5.338
	(0.0031)		(0.0045)		(0.0048)		(0.0115)	
Operating cost	-0.083*	-0.381	0.100	0.391	-0.032	-0.154	-0.161	-0.787
	(0.0478)		(0.1269)		(0.0268)		(0.2421)	
Term spread (asset)	-0.155***	-0.153	-0.090***	-0.092	-0.155***	-0.152	-0.168*	-0.164
	(0.0175)		(0.0217)		(0.0251)		(0.0860)	
Excess capital	0.046***	0.287	0.039***	0.208	0.060***	0.394	-0.006	-0.034
	(0.0056)		(0.0076)		(0.0075)		(0.0219)	
Duration gap	0.337***	0.564	0.370***	0.588	0.567***	0.976	-0.046	-0.054
	(0.0505)		(0.0673)		(0.0715)		(0.1335)	
LIBOR volatility	1.501***	0.967	0.993***	0.644	1.445***	0.930	1.671***	1.045
	(0.1049)		(0.1227)		(0.1346)		(0.2797)	
Credit risk	0.020***	2.178	0.020***	2.070	0.017***	1.927	0.019**	2.193
	(0.0017)		(0.0021)		(0.0015)		(0.0095)	
Credit-interest covariance	-0.010***	-0.150	-0.009***	-0.144	-0.009***	-0.138	-0.014***	-0.217
	(0.0004)		(0.0006)		(0.0004)		(0.0031)	
Bank-specific variables								
NII	0.570***	0.793	1.250***	1.509	0.427***	0.618	0.618*	1.132
	(0.0879)		(0.3546)		(0.0812)		(0.3514)	
IIP	0.239***	0.656	0.152*	0.355	0.184***	0.536	0.404**	0.877
	(0.0332)		(0.0778)		(0.0189)		(0.2005)	
OCR	0.101***	0.186	0.118***	0.188	0.099***	0.196	-0.145	-0.114
	(0.0124)		(0.0317)		(0.0156)		(0.1259)	
Macroeconomic variables								
GDP growth	0.081***	0.140	0.055***	0.095	0.098***	0.171	0.126***	0.227
	(0.0063)		(0.0097)		(0.0092)		(0.0323)	
Inflation rate	0.283***	0.856	0.250***	0.760	0.265***	0.801	0.235***	0.683
	(0.0233)		(0.0315)		(0.0326)		(0.0721)	
Revolving portfolios								
Loans to banks								
daily	2.208***	0.589	2.207***	0.320	2.465***	0.762	2.120***	0.793
	(0.1171)		(0.1460)		(0.1744)		(0.3395)	
$\leq$ 1 y.	1.976***	0.454	2.042***	0.530	2.112***	0.434	1.828***	1.126
	(0.0997)		(0.1340)		(0.1425)		(0.2509)	
$>$ 1 y. $\leq$ 5 y.	1.626***	0.278	1.680***	0.124	1.717***	0.362	1.784***	0.124
	(0.0706)		(0.1082)		(0.0996)		(0.4567)	
$>$ 5 y.	1.217***	0.199	1.310***	0.194	1.229***	0.212	1.028***	0.078
	(0.0518)		(0.0805)		(0.0642)		(0.3521)	
Loans to non-banks								
$\leq$ 1 y.	2.162***	1.052	3.012***	1.338	2.750***	1.312	1.505***	1.836
	(0.1653)		(0.2245)		(0.1546)		(0.2596)	
$>$ 1 y. $\leq$ 5 y.	1.551***	0.615	1.590***	0.399	1.636***	0.711	1.243***	1.131
	(0.0647)		(0.1441)		(0.0699)		(0.2858)	
$>$ 5 y.	1.120***	4.942	1.015***	4.866	1.089***	4.721	1.185***	2.806
	(0.0252)		(0.0303)		(0.0263)		(0.2162)	
Bonds held								
$\leq$ 1 y.	0.778***	0.011	1.002***	0.016	0.782***	0.011	-1.651	-0.016
	(0.0894)		(0.1451)		(0.1002)		(1.1166)	
$>$ 1 y. $\leq$ 2 y.	0.974***	0.043	1.155***	0.062	1.077***	0.044	0.669	0.039
	(0.0629)		(0.0762)		(0.0771)		(0.5095)	
$>$ 2 y.	0.607***	0.883	0.765***	1.222	0.570***	0.805	0.316**	0.351
	(0.0221)		(0.0486)		(0.0239)		(0.1360)	
Obs.	16,396		4,479		11,524		393	
Number of synthetic banks	2,380		594		1,730		56	
GR^2	0.866		0.896		0.890		0.648	
Underid. LM stat. [p-val.]	92.89	[0]	52.59	[0]	48.90	[0]	7.764	[0.005]
Cragg-Donald F-test	118.4		70.15		48.20		5.191	

Dependent variable: interest income margin (IIM). Operating cost, non-interest income (NII), opportunity cost of reserves (OCR) and implicit interest payments (IIP) are in relation to interest-earning assets. All models have been estimated using fixed effects 2-SLS IV regressions, where Lerner index (assets) and NII have been instrumented with their own first differences. Underid. gives the LM statistic and the p-value for the Kleibergen and Paap (2006) rank test of underidentification. Cragg-Donald F-test gives the Cragg-Donald statistic based on Kleibergen and Paap's rank of the matrix. Elasticities of variables are displayed on the right next to coefficients and have been calculated at sample mean and multiplied by the factor 10. Elasticities have been estimated using chain rules, and have been multiplied by -10 if evaluated at a negative sample mean. Standard errors are given in parentheses and are clustered at bank level. Significance at the 10%/5%/1%-level is marked by */**/***. GR^2 is the generalized R^2 criterion of Pesaran and Smith (1994) for 2-SLS IV estimation.

Table 3.5: Determinants of Interest Expense Margin (IEM)

	Total sample (i)		Savings banks (ii)		Cooperative banks (iii)		Other banks (iv)	
	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.
Lerner index (deposits)	-0.010***	-0.822	-0.014***	-1.122	-0.008***	-0.704	-0.019***	-1.792
	(0.0005)		(0.0008)		(0.0004)		(0.0035)	
Operating cost	-0.190***	-1.679	-0.388***	-2.649	-0.209***	-2.018	-0.042	-0.418
	(0.0358)		(0.0536)		(0.0152)		(0.2087)	
Term spread (liabilities)	0.010**	0.017	0.009	0.016	0.022***	0.037	0.017	0.030
	(0.0049)		(0.0085)		(0.0050)		(0.0467)	
Excess capital	-0.001	-0.016	0.014***	0.135	-0.002	-0.026	-0.035***	-0.366
	(0.0029)		(0.0053)		(0.0026)		(0.0114)	
Duration gap	0.042**	0.135	0.012	0.035	0.082***	0.280	0.005	0.011
	(0.0177)		(0.0293)		(0.0188)		(0.1204)	
LIBOR volatility	0.125***	0.156	0.097***	0.114	0.111***	0.142	0.091	0.107
	(0.0147)		(0.0220)		(0.0143)		(0.1442)	
Credit-interest covariance	-0.006***	-0.186	-0.006***	-0.181	-0.006***	-0.192	-0.012***	-0.333
	(0.0003)		(0.0003)		(0.0002)		(0.0028)	
NII	0.365***	0.976	1.252***	2.627	0.397***	1.140	-0.039	-0.143
	(0.0858)		(0.1368)		(0.0348)		(0.3519)	
IIP	0.050**	0.265	0.135***	0.552	0.048***	0.279	-0.028	-0.122
	(0.0198)		(0.0430)		(0.0108)		(0.1570)	
OCR	-0.034***	-0.120	-0.010	-0.028	-0.038***	-0.149	-0.065	-0.103
	(0.0076)		(0.0144)		(0.0071)		(0.0734)	
GDP growth	0.007**	0.024	0.006	0.020	0.003	0.011	0.092***	0.309
	(0.0034)		(0.0052)		(0.0030)		(0.0322)	
Inflation rate	-0.022***	-0.128	0.020***	0.109	-0.043***	-0.262	0.007	0.036
	(0.0062)		(0.0075)		(0.0051)		(0.0483)	
Revolving portfolios								
Loans from banks daily	0.889***	0.049	1.076***	0.107	0.813***	0.025	0.836***	0.172
	(0.0504)		(0.0659)		(0.0687)		(0.1828)	
$\leq$ 1 y.	0.798***	0.126	0.906***	0.248	0.657***	0.058	1.201***	0.877
	(0.0693)		(0.0408)		(0.0429)		(0.1346)	
$>$ 1 y. $\leq$ 2 y.	0.671***	0.022	0.733***	0.028	0.563***	0.016	1.174***	0.121
	(0.0576)		(0.0946)		(0.0762)		(0.2031)	
$>$ 2 y.	0.869***	1.938	0.975***	2.639	0.919***	1.902	1.014***	1.287
	(0.0246)		(0.0271)		(0.0215)		(0.1108)	
Loans from non-banks daily	0.848***	2.013	1.177***	2.475	0.761***	1.887	1.061***	2.698
	(0.0327)		(0.0538)		(0.0299)		(0.1609)	
$\leq$ 1 y.	0.971***	1.363	1.040***	0.880	0.926***	1.479	1.217***	2.961
	(0.0209)		(0.0434)		(0.0192)		(0.1401)	
$>$ 1 y. $\leq$ 2 y.	1.045***	0.226	1.113***	0.131	0.973***	0.250	1.198***	0.259
	(0.0474)		(0.0961)		(0.0434)		(0.3650)	
$>$ 2 y.	0.848***	0.823	0.914***	0.792	0.839***	0.840	0.867***	1.132
	(0.0396)		(0.0464)		(0.0306)		(0.1307)	
Subordinated debt	0.908***	0.079	0.498***	0.099	1.938***	0.078	1.375	0.113
	(0.1238)		(0.1336)		(0.2632)		(1.2662)	
Saving accounts $\leq$ 3 m.	0.809***	3.550	0.927***	3.561	0.782***	3.674	0.891***	1.893
	(0.0164)		(0.0290)		(0.0152)		(0.1052)	
$>$ 3 m.	0.777***	0.760	0.905***	1.039	0.752***	0.693	0.956***	0.582
	(0.0182)		(0.0318)		(0.0199)		(0.1703)	
Bonds issued $\leq$ 1 y.	0.143	0.001	-0.140	-0.001	0.300	0.001	0.591	0.008
	(0.1977)		(0.2632)		(0.3571)		(1.0066)	
$>$ 1 y. $\leq$ 2 y.	0.213**	0.007	0.058	0.002	0.265***	0.009	1.231	0.023
	(0.0918)		(0.1608)		(0.0999)		(1.5459)	
$>$ 2 y.	0.437***	0.175	0.400***	0.147	0.521***	0.219	0.903*	0.229
	(0.0424)		(0.0707)		(0.0439)		(0.4808)	
GR^2	0.869		0.882		0.883		0.787	
Underid. LM stat. [p-val.]	98.66	[0]	207.5	[0]	606.3	[0]	7.966	[0.005]
Cragg-Donald F-test	88.79		218.3		2516		5.619	

Dependent variable: interest expense margin (IEM). Operating cost, non-interest income (NII), opportunity cost of reserves (OCR) and implicit interest payments (IIP) are in relation to interest-paying liabilities. All models have been estimated using fixed effects 2-SLS IV regressions, where Lerner index (deposits) and NII have been instrumented with their own first differences. Underid. gives the LM statistic and the p-value for the Kleibergen and Paap (2006) rank test of underidentification. Cragg-Donald F-test gives the Cragg-Donald statistic based on Kleibergen and Paap's rank of the matrix. Elasticities of variables are displayed on the right next to coefficients and have been calculated at sample mean and multiplied by the factor 10. Elasticities have been estimated using chain rules, and have been multiplied by -10 if evaluated at a negative sample mean. Standard errors are given in parentheses and are clustered at bank level. Significance at the 10%/5%/1%-level is marked by */**/***. GR^2 is the generalized R^2 criterion of Pesaran and Smith (1994) for 2-SLS IV estimation.

Concerning a bank's risk aversion, measured by its excess capital, positive and significant (except for other banks) coefficients are found on the asset side. However, results (sign and significance) are mixed for the liability side.[17]

Credit risk has the expected positive sign and is significant. The correlation between interest and credit risk is significantly negative for both the asset and liability side. The positive effect on the NIM is, therefore, explained by the higher magnitude of the elasticities on the liability side. However, the negative coefficients contradict the model's predictions.

To summarize, in line with our model predictions, we find that loan fees depend negatively on expected holding period returns and positively on macroeconomic interest rate risk (LIBOR volatility) and microeconomic duration gaps. This means that banks pass part of the positive expected holding period returns to customers but price higher risk charges when loans compound a large duration gap and when interest rate uncertainty is high. On the liability side, we do not find an economically relevant impact of expected excess holding period returns. This suggests that banks do not charge higher fees in deposits as a means of compensation for higher valuation risk compared to funding in the money market. However, we find strong evidence that macroeconomic interest rate risk is priced. Our results on the impact of the duration gaps are mixed, suggesting that the effect, if it exists, is not strong and only valid for the smallest of the banks in our sample, i.e. cooperative banks. The different pictures for assets and liabilities imply that the results for the NIM are mainly driven by the asset side.

[17] Focusing on short-term bank rates rather than intermediation fees in Italy, Gambacorta (2008) finds that high endowments of excess capital lead to significantly different loan rate adjustments, however not for deposit rates, which is consistent with our results.

3.5.4 Impact of Financial Crisis

The last two years of our sample period 2000 to 2009 are years of financial turmoil. Although the German banking system was on the whole less affected than other systems, some of our results might have been influenced by this time of high uncertainty. To analyze possible effects, we repeat the regressions from Tables 3.3 to 3.5, but additionally interact the variables we are most interested in, i.e. term spread, duration gap, and LIBOR volatility with a dummy for the crisis years 2008 and 2009. We also interact excess capital as a proxy for risk aversion that may play an important role in crisis times. It should be noted as the LIBOR volatility is not bank-specific, any estimation of the impact of the interacted LIBOR volatility may suffer from the absence of cross-sectional variation since it covers only two years in the time series dimension.

Tables 3.6, 3.7, and 3.8 report the results for the NIM, the IIM, and IEM, respectively. For the sake of brevity, they do so only for the model-derived variables. In the following, we concentrate our analysis on the four variables which we interacted.

First, examining results for the NIM in Table 3.6 we find the non-interacted coefficients of the term spread are again negative, and in general slightly more pronounced and of the same significance compared to the whole sample period reported in Table 3.3. They range from -0.07 for savings and cooperative banks to -0.055 for other banks. The interacted coefficients capturing the diverging impact during the financial crisis are positive and exceed those previously presented in terms of their magnitude (from 0.381 to 0.126). The respective sums of both coefficients (e.g., -0.07 + 0.381 = 0.311 for savings banks) represent the pricing impact during the financial crisis. They are positive and tests are highly significant (p-values are provided on the bottom of the table) for all but the other bank sample. This suggests that the negative impact of the term spread on net intermediation fees — as predicted by our model — holds but was distorted during the financial crisis.

Analogous analyses for the remaining variables show that microeconomic duration gap and the macroeconomic LIBOR volatility keep their sign and significance in the crisis

Table 3.6: Determinants of Net Interest Margin (NIM) with Crisis Interactions

	Total sample (i)		Savings banks (ii)		Cooperative banks (iii)		Other banks (iv)	
	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.
Lerner index (overall)	0.073***	11.496	0.073***	13.688	0.077***	11.405	0.059***	7.957
	(0.0037)		(0.0045)		(0.0041)		(0.0144)	
Operating cost	1.345***	12.785	1.417***	12.935	1.507***	14.493	0.824***	8.031
	(0.0898)		(0.1362)		(0.0860)		(0.2701)	
Term spread (asset-liability)	-0.065***	-0.018	-0.070***	-0.016	-0.070***	-0.021	-0.055	-0.002
	(0.0068)		(0.0110)		(0.0071)		(0.0479)	
Term spread × Crisis	0.317***	0.080	0.381***	0.118	0.334***	0.081	0.126	0.015
	(0.0315)		(0.0491)		(0.0315)		(0.1553)	
Excess capital	0.061***	0.885	0.112***	1.613	0.055***	0.796	0.026	0.322
	(0.0048)		(0.0112)		(0.0048)		(0.0174)	
Excess capital × Crisis	-0.005**	-0.019	-0.017***	-0.065	-0.004*	-0.015	0.047*	0.095
	(0.0024)		(0.0065)		(0.0026)		(0.0254)	
Duration gap	0.248***	0.963	0.285***	1.222	0.237***	0.903	0.129	0.327
	(0.0229)		(0.0444)		(0.0304)		(0.1649)	
Duration gap × Crisis	-0.068***	-0.058	-0.090**	-0.085	-0.055	-0.046	-0.051	-0.026
	(0.0255)		(0.0418)		(0.0350)		(0.0912)	
LIBOR volavility	1.604***	2.405	1.616***	2.824	1.676***	2.392	1.107***	1.502
	(0.0773)		(0.1105)		(0.0896)		(0.2895)	
LIBOR volatility × Crisis	-0.927***	-0.363	-0.829***	-0.388	-1.041***	-0.387	-0.705***	-0.220
	(0.0613)		(0.1055)		(0.0710)		(0.1659)	
Credit risk	0.000	0.121	0.002	0.500	0.000	0.046	0.001	0.277
	(0.0007)		(0.0013)		(0.0008)		(0.0046)	
Credit-interest covariance	0.021***	0.757	0.020***	0.856	0.023***	0.784	0.017***	0.571
	(0.0016)		(0.0019)		(0.0018)		(0.0063)	
Significance in crisis								
Term spread [p-val.]	80.22	[0]	49.38	[0]	87.07	[0]	0.203	[0.652]
Excess capital [p-val.]	155.2	[0]	114.2	[0]	125.1	[0]	6.302	[0.012]
Duration gap [p-val.]	56.71	[0]	16.52	[0]	43.61	[0]	0.280	[0.596]
LIBOR volatility [p-val.]	76.19	[0]	40.20	[0]	33.45	[0]	2.227	[0.136]
Obs.	16,396		4,479		11,524		393	
Number of synthetic banks	2,380		594		1,730		56	
GR^2	0.552		0.483		0.607		0.391	
Underid. LM stat. [p-val.]	90.63	[0]	59.02	[0]	63.96	[0]	7.709	[0.006]
Cragg-Donald F-test	77.88		47.76		57.08		5.671	

Variables previously denoted *Bank-specific variables*, *Macroeconomic variables*, and *Revolving portfolios* have been included in the regressions, but are, for the purpose of brevity, not displayed. Term spread (asset-liability), Excess capital, Duration gap, and LIBOR volatility have additionally been interacted with a crisis dummy, indicating the years 2008 and 2009. Significance in crisis reports values and p-values of the Wald test of the sum of the parameters of the non-interacted variable and the variable interacted with the crisis dummy (variable × crisis). All models have been estimated using fixed effects 2-SLS IV regressions, where the specific Lerner index and NII (not displayed) have been instrumented with their own first differences. Underid. gives the LM statistic and the p-value for the Kleibergen and Paap (2006) rank test of underidentification. Cragg-Donald F-test gives the Cragg-Donald statistic based on Kleibergen and Paap's rank of the matrix. Elasticities of variables are displayed on the right next to coefficients and have been calculated at sample mean and multiplied by the factor 10. Elasticities have been estimated using chain rules, and have been multiplied by -10 if evaluated at a negative sample mean. Standard errors are given in parentheses and are clustered at bank level. Significance at the 10%/5%/1%-level is marked by */**/***. GR^2 is the generalized R^2 criterion of Pesaran and Smith (1994) for 2-SLS IV estimation.

Table 3.7: Determinants of Interest Income Margin (IIM) with Crisis Interactions

	Total sample (i)		Savings banks (ii)		Cooperative banks (iii)		Other banks (iv)	
	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.
Lerner index (assets)	0.060***	5.455	0.049***	4.695	0.066***	5.954	0.067***	5.565
	(0.0041)		(0.0060)		(0.0066)		(0.0120)	
Operating cost	-0.395***	-1.817	-0.370***	-1.452	-0.530***	-2.563	-0.159	-0.778
	(0.0624)		(0.1284)		(0.0599)		(0.2509)	
Term spread (asset)	-0.199***	-0.198	-0.139***	-0.143	-0.161***	-0.158	-0.171*	-0.166
	(0.0237)		(0.0271)		(0.0288)		(0.0930)	
Term spread × Crisis	0.386***	0.108	0.300***	0.089	0.618***	0.171	-0.615*	-0.114
	(0.0714)		(0.0795)		(0.0771)		(0.3487)	
Excess capital	0.041***	0.254	0.040***	0.212	0.056***	0.366	-0.014	-0.079
	(0.0070)		(0.0089)		(0.0075)		(0.0199)	
Excess capital × Crisis	-0.006	-0.009	0.003	0.004	-0.016***	-0.024	0.028	0.026
	(0.0040)		(0.0069)		(0.0040)		(0.0401)	
Duration gap	0.375***	0.627	0.449***	0.714	0.520***	0.895	0.083	0.097
	(0.0464)		(0.0884)		(0.0742)		(0.1051)	
Duration gap × Crisis	-0.047	-0.017	-0.110**	-0.039	-0.041	-0.015	0.153	0.036
	(0.0323)		(0.0499)		(0.0310)		(0.1318)	
LIBOR volatility	3.389***	2.185	2.355***	1.527	3.641***	2.345	3.154***	1.973
	(0.2598)		(0.2704)		(0.3861)		(0.6412)	
LIBOR volatility × Crisis	-3.261***	-0.550	-2.530***	-0.439	-3.852***	-0.646	-1.687**	-0.243
	(0.2968)		(0.3122)		(0.4097)		(0.7597)	
Credit risk	0.008***	0.850	0.010***	1.069	0.005***	0.508	0.015*	1.666
	(0.0017)		(0.0018)		(0.0010)		(0.0084)	
Credit-interest covariance	-0.036***	-0.574	-0.030***	-0.476	-0.043***	-0.677	-0.027***	-0.407
	(0.0024)		(0.0024)		(0.0037)		(0.0063)	
Significance in crisis								
Term spread [p-val.]	6.532	[0.011]	5.583	[0.018]	60.32	[0]	4.594	[0.032]
Excess capital [p-val.]	22.80	[0]	19.35	[0]	35.82	[0]	0.0883	[0.766]
Duration gap [p-val.]	37.93	[0]	18.09	[0]	50.95	[0]	2.737	[0.098]
LIBOR volatility [p-val.]	0.567	[0.451]	1.650	[0.199]	6.255	[0.012]	14.97	[0]
GR^2	0.868		0.896		0.891		0.661	
Underid. LM stat. [p-val.]	72.75	[0]	36.73	[0]	37.00	[0]	7.797	[0.005]
Cragg-Donald F-Test	97.96		62.26		37.08		5.171	

Variables previously denoted *Bank-specific variables*, *Macroeconomic variables*, and *Revolving portfolios* have been included in the regressions, but are, for the purpose of brevity, not displayed. Term spread, Excess capital, Duration gap, and LIBOR volatility have additionally been interacted with a crisis dummy, indicating the years 2008 and 2009. Significance in crisis reports values and p-values of the Wald test of the sum of the parameters of the non-interacted variable and the variable interacted with the crisis dummy (variable × crisis). All models have been estimated using fixed effects 2-SLS IV regressions, where Lerner index and NII (not displayed) have been instrumented with their own first differences. Underid. gives the LM statistic and the p-value for the Kleibergen and Paap (2006) rank test of underidentification. Cragg-Donald F-test gives the Cragg-Donald statistic based on Kleibergen and Paap's rank of the matrix. Elasticities of variables are displayed on the right next to coefficients and have been calculated at sample mean and multiplied by the factor 10. Elasticities have been estimated using chain rules, and have been multiplied by -10 if evaluated at a negative sample mean. Standard errors are given in parentheses and are clustered at bank level. Significance at the 10%/5%/1%-level is marked by */**/***. GR^2 is the generalized R^2 criterion of Pesaran and Smith (1994) for 2-SLS IV estimation.

Table 3.8: Determinants of Interest Expense Margin (IEM) with Crisis Interactions

	Total sample (i)		Savings banks (ii)		Cooperative banks (iii)		Other banks (iv)	
	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.	Coeff.	Elast.
Lerner index (deposits)	-0.010***	-0.894	-0.017***	-1.381	-0.009***	-0.775	-0.021***	-1.957
	(0.0005)		(0.0011)		(0.0005)		(0.0039)	
Operating cost	-0.235***	-2.080	-0.582***	-3.971	-0.264***	-2.546	-0.055	-0.543
	(0.0459)		(0.0686)		(0.0211)		(0.2125)	
Term spread (liabilities)	0.009*	0.015	-0.010	-0.017	0.027***	0.045	0.010	0.018
	(0.0048)		(0.0093)		(0.0049)		(0.0528)	
Term spread × Crisis	-0.034	-0.011	-0.043	-0.014	-0.048**	-0.016	0.008	0.002
	(0.0211)		(0.0390)		(0.0231)		(0.2283)	
Excess capital	0.004	0.051	0.034***	0.326	0.002	0.020	-0.028**	-0.291
	(0.0032)		(0.0060)		(0.0028)		(0.0131)	
Excess capital × Crisis	-0.008***	-0.023	-0.022***	-0.055	-0.002	-0.005	-0.038	-0.067
	(0.0028)		(0.0051)		(0.0029)		(0.0272)	
Duration gap	0.018	0.059	-0.024	-0.069	0.036*	0.125	-0.055	-0.121
	(0.0189)		(0.0335)		(0.0192)		(0.1103)	
Duration gap × Crisis	0.050**	0.036	-0.007	-0.005	0.125***	0.093	0.205**	0.090
	(0.0214)		(0.0313)		(0.0235)		(0.0849)	
LIBOR volatility	0.321***	0.401	0.674***	0.791	0.317***	0.407	0.319	0.375
	(0.0496)		(0.0610)		(0.0354)		(0.2413)	
LIBOR volatility × Crisis	-0.275***	-0.090	-0.657***	-0.206	-0.486***	-0.162	-0.408	-0.110
	(0.0819)		(0.1150)		(0.0784)		(0.4426)	
Credit-interest covariance	-0.009***	-0.268	-0.014***	-0.399	-0.009***	-0.293	-0.015***	-0.440
	(0.0009)		(0.0010)		(0.0006)		(0.0051)	
Significance in crisis								
Term spread [p-val.]	1.430	[0.232]	1.868	[0.172]	0.878	[0.349]	0.006	[0.939]
Excess capital [p-val.]	1.203	[0.273]	3.732	[0.053]	0.004	[0.952]	5.379	[0.020]
Duration gap [p-val.]	8.350	[0.004]	0.612	[0.434]	34.61	[0]	0.938	[0.333]
LIBOR volatility [p-val.]	0.723	[0.395]	0.0421	[0.837]	6.887	[0.009]	0.071	[0.790]
GR^2	0.869		0.883		0.884		0.792	
Underid. LM stat. [p-val.]	91.07	[0]	173.6	[0]	561.3	[0]	8.188	[0.004]
Cragg-Donald F-Test	72.30		195.4		1314		6.048	
Obs.	16,396		4,479		11,524		393	
Number of synthetic banks	2,380		594		1,730		56	

Variables previously denoted *Bank-specific variables*, *Macroeconomic variables*, and *Revolving portfolios* have been included in the regressions, but are, for the purpose of brevity, not displayed. Term spread, Excess capital, Duration gap, and LIBOR volatility have additionally been interacted with a crisis dummy, indicating the years 2008 and 2009. Significance in crisis reports values and p-values of the Wald test of the sum of the parameters of the non-interacted variable and the variable interacted with the crisis dummy (variable × crisis). All models have been estimated using fixed effects 2-SLS IV regressions, where Lerner index and NII (not displayed) have been instrumented with their own first differences. Underid. gives the LM statistic and the p-value for the Kleibergen and Paap (2006) rank test of underidentification. Cragg-Donald F-test gives the Cragg-Donald statistic based on Kleibergen and Paap's rank of the matrix. Elasticities of variables are displayed on the right next to coefficients and have been calculated at sample mean and multiplied by the factor 10. Elasticities have been estimated using chain rules, and have been multiplied by -10 if evaluated at a negative sample mean. Standard errors are given in parentheses and are clustered at bank level. Significance at the 10%/5%/1%-level is marked by */**/***. GR^2 is the generalized R^2 criterion of Pesaran and Smith (1994) for 2-SLS IV estimation.

years, except for other banks where LIBOR volatility becomes insignificant. Likewise for savings and cooperative banks, the initial coefficient of LIBOR volatility is reduced by more than 50% during the financial crisis.

Regarding excess capital, we find that the financial crisis had no economically relevant impact in the case of savings and cooperative banks. For the sample of other banks, non-interacted coefficients are insignificant, but adding the interacted coefficient turns the overall effect significantly positive with a p-value of 1.2%. This implies the overall effect for other banks found in Table 3.3 is mainly driven by the financial crisis, a time when equity was of the greatest value to them.

Turning to the disentangled results for interest income and expenses in Table 3.7 and 3.8, we see that the positive effect of the term spread on the NIM during the crisis years is driven by the asset side. Non-interacted coefficients are significantly negative for the IIM in all samples, in line with expectations. However, high positive interacted coefficients (except for other banks) overcompensate these effects during the financial crisis. Only in the case of other banks are the interacted coefficients highly negative, and therefore strengthening the negative impact observed for the non-interacted coefficients. By contrast, for liabilities, the sum of coefficients capturing the effect of the term spread during the financial crisis is not significant in any regression. During normal times, again, we observe slightly positive significant coefficients solely for cooperative banks, as already shown in Table 3.5.

For the duration gap, in qualitative terms, we find the same results for the asset side as in our previous analyses. It is positively priced in both normal times and the crisis years, expect for other banks due to insignificant effects. On the liability side, we find the expected positive coefficients during normal times solely for the cooperative banks sample. However, interacted coefficients are significantly positive for cooperative and other banks and almost four times as high as in the non-interacted case. The overall effect during the financial crisis, i.e. the sum of coefficients, is positive and significant for the cooperative banks. The significance in the other bank sample might again suffer from the small sample size. This suggests that many banks with a higher duration gap reduced deposit fees in the crisis years in order to stabilize their funding at a time when external finance, in general, was more expensive.

A surprising effect can be found for LIBOR volatility, however as mentioned above this has to be interpreted with caution. Whereas the non-interacted coefficients for both the asset and liability side are positive and significant as in the previous analyses of Tables 3.4 and 3.5, the interacted coefficients are negative and highly significant, leading to an insignificant combined effect in most cases. On the asset side, the effect only remains significant for other banks, however turns significantly negative for cooperatives. Remembering the reduced coefficients found for the NIM, the analysis suggests banks were not able to price the record high volatility in interbank market rates during the financial crisis in the same magnitude as LIBOR volatility during normal times.

With regard to excess capital endowments, against the predictions of the theoretical model we find still a significantly positive impact for cooperative banks on the liability side. However, the crisis led to a significant reduction in the previously observed effect. For other banks, the crisis enforced the pricing of equity in line with the model, i.e. excess capital leads to reductions in interest expenses. On the asset side, no significantly different pricing pattern can be observed.

3.6 Concluding Remarks

In this paper, we analyze how interest risk exposure from maturity transformation is priced in banks' intermediation fees. We extend the theoretical dealership model of Ho and Saunders (1981) to incorporate loans and deposits with differing maturities, making the bank sensitive to valuation interest risk when positive shifts in the yield curve lead to a declining market value of equity. Thereby, we explicitly integrate one of the central functions of financial intermediation, that of maturity transformation, into the model. The model implies that the fees banks charge on loans and deposits depend on both the macroeconomic risk of unexpected changes in interest rates and the bank-specific microeconomic exposure to this risk, i.e. the maturity gap, as well as expected holding period returns from maturity transformation.

We test the model-implied hypotheses for the German commercial banking sector, a bank-based financial system in which maturity transformation evolves as a consequence of liquidity creation by financial intermediaries. Many of these, especially small and medium-sized banks, manage interest risk on-balance, which makes the dataset suitable for our analysis.

In contrast to earlier studies, we investigate — additionally to net interest income — the interest income and expense margin separately. Our results show that all banks price the macroeconomic risk of interest rate volatility. The microeconomic risk of the specific on-balance duration gap is priced by the savings and cooperative banks in the net interest income margin and these results are driven via loan pricing on the asset side. On the liability side, we find that interest rate risk exposure is priced only by cooperative banks. The fees of larger private commercial banks with access to capital markets, on the other hand, are not sensitive to on-balance interest rate risk.

Appendix A

Lerner indices

A single-product Lerner index is defined as the output price minus marginal cost divided by price, and equals the inverse of elasticity of demand for the output:

$$\frac{i^*{}_{TA} - mc_{\ TA}}{i^*{}_{TA}} = \frac{1}{N\epsilon_{\ TA}\left(i^*{}_{TA}\right)}, \tag{A.0.1}$$

where $mc_{\ TA}$ are marginal costs encompassing financial expenses. $\epsilon_{\ TA}$ represents the elasticity of output demand in a market encompassing N banks. The output price i (the interest rate that the bank charges) is assumed to be exogenous and is proxied by interest income / interest-earning assets. Marginal costs for overall market power are estimated from a single-output (total assets, TA), three-input translog cost function. The input prices comprise: (i) cost of labor w_1, (ii) cost of physical capital w_2, (iii) and cost of funding w_3. The input prices have been proxied as: (i) w_1 personnel cost / number of full-time equivalent employees measured in 1,000; (ii) w_2 operating cost excluding personnel cost / fixed assets; (iii) w_3 interest expenses paid / total interest-paying liabilities. Equity Eq is included as a netput and a time trend Tr, specified as time dummies, captures technical change. The translog cost function has the following form and is estimated using fixed bank effects to control for unobserved heterogeneity. The usual symmetry and linear homogeneity in input price restrictions are imposed.

$$
\begin{aligned}
\ln c_{it} =& \gamma_i + \gamma_A \ \ln TA_{it} + \frac{1}{2}\gamma_{AA} \ (\ln TA_{it})^2 + \sum_{h=1}^{3} \gamma_h \ \ln w_{hit} \\
&+ \frac{1}{2}\sum_{h=1}^{3}\sum_{m=1}^{3} \gamma_{hm} \ \ln w_{hit} \ \ln w_{mit} + \sum_{h=1}^{3} \gamma_{hA} \ \ln w_{hit} \ \ln TA_{it} + \gamma_E \ \ln Eq_{it} \\
&+ \frac{1}{2}\gamma_{EE} (\ln Eq_{it})^2 + \gamma_{EA} \ \ln Eq_{it} \ \ln TA_{it} + \sum_{h=1}^{3} \gamma_{hE} \ \ln w_{hit} \ \ln Eq_{it} \\
&+ \gamma_T \ Tr + \frac{1}{2}\gamma_{TT} \ (Tr)^2 + \gamma_{TA} \ Tr \ \ln TA_{it} \\
&+ \sum_{h=1}^{3} \gamma_{Th} \ Tr \ \ln w_{hit} + \gamma_{TE} \ Tr \ \ln Eq_{it} + \ln u_{it}.
\end{aligned} \tag{A.0.2}
$$

Marginal costs $mc_{\ TA_{it}}$ are derived from

$$
mc_{TA_{it}} = \Big[\gamma_A + \gamma_{AA} \ \ln TA_{it} + \sum_{h=1}^{3} \gamma_{hA} \ \ln w_{hit} + \gamma_{EA} \ \ln Eq_{it} + \gamma_{TA} \ Tr\Big] \frac{c_{it}}{TA_{it}}. \tag{A.0.3}
$$

Separate Lerner indices for interest-bearing assets and liabilities are derived from first-order conditions of profit maximization in the Monti-Klein model and expressed as (see Freixas and Rochet, 2008, p. 58):

$$
\frac{i^*_{\ L} - i - mc_{\ L}}{i^*_{\ L}} = \frac{1}{N\epsilon_{\ L}\left(i^*_{\ L}\right)}; \qquad \frac{i - i^*_{\ D} - mc_{\ D}}{i^*_{\ D}} = \frac{1}{N\epsilon_{\ D}\left(i^*_{\ D}\right)} \tag{A.0.4}
$$

where $i_{\ L}$, $i_{\ D}$ and i are the interest rates set on loans, deposits and the interbank market, respectively. To estimate the marginal cost, we follow the two-product output approach of Maudos and Fernández de Guevara (2007). $i_{\ L}$ is proxied to equal interest income / interest-earning assets, and $i_{\ D}$ equals interest expenses / interest-paying liabilities. The yearly average of the six-month LIBOR rate presents the interbank funding rate. Marginal costs are estimated using a two-product output translog cost function, including loans L and deposits D. Loans are proxied by interest-earning assets less bonds held and deposits as total interest-paying liabilities less bonds issued.[18] The interbank rate is clearly

[18] It is assumed that bond supply and demand are perfectly elastic, that the bank cannot exercise market power in trading bonds, and that bond portfolios are not associated with operating cost. Statistically, bond portfolios have been excluded to make the loan and the deposit proxies less correlated to each other. For the same reason, the impact of equity is not controlled for as equity and interest-paying liabilities would otherwise almost total interest-earning assets.

exogenous, and interest expenses on liabilities are now considered to be the output price of deposits, so that we only include the two price input factors of labor (w_1), and physical capital (w_2), which are defined in the same way as in the three-input cost function. Again time dummies control for technical change, and fixed bank effects control for unobserved heterogeneity. The translog cost function takes the following form:

$$\begin{aligned}
\ln c_{it} =& \gamma_i + \gamma_L \ \ln L_{it} + \frac{1}{2}\gamma_{LL} \ (\ln L_{it})^2 + \gamma_D \ \ln D_{it} + \frac{1}{2}\gamma_{DD} \ (\ln D_{it})^2 \\
&+ \gamma_{LD} \ \ln L_{it} \ \ln D_{it} + \sum_{h=1}^{2} \gamma_h \ \ln w_{hit} + \frac{1}{2} \sum_{h=1}^{2} \sum_{m=1}^{2} \gamma_{hm} \ \ln w_{hit} \ \ln w_{mit} \\
&+ \sum_{h=1}^{2} \gamma_{hL} \ \ln w_{hit} \ \ln L_{it} + \sum_{h=1}^{2} \gamma_{hD} \ln w_{hit} \ \ln D_{it} + \gamma_T \ Tr + \frac{1}{2}\gamma_{TT} \ (Tr)^2 \\
&+ \gamma_{TL} \ Tr \ln L_{it} + \gamma_{TD} \ Tr \ \ln D_{it} + \sum_{h=1}^{2} \gamma_{Th} \ Tr \ \ln w_{hit} + \ln u_{it}.
\end{aligned} \tag{A.0.5}$$

The cost function has been estimated using fixed bank effects. Marginal cost are derived from:

$$\begin{aligned}
mc_{\ L_{it}} =& \Big[\gamma_L + \gamma_{LL} \ \ln L_{it} + \gamma_{LD} \ \ln D_{it} + \sum_{h=1}^{2} \gamma_{hL} \ \ln w_{hit} + \gamma_{TL} \ Tr\Big] \frac{c_{it}}{L_{it}} \\
mc_{\ D_{it}} =& \Big[\gamma_D + \gamma_{DD} \ \ln D_{it} + \gamma_{LD} \ \ln L_{it} + \sum_{h=1}^{2} \gamma_{hD} \ \ln w_{hit} + \gamma_{TD} \ Tr\Big] \frac{c_{it}}{D_{it}}.
\end{aligned} \tag{A.0.6}$$

Appendix B

Modified duration gaps

Table B.1 provides an overview of the different lender and borrower clienteles and the time brackets reported in the Deutsche Bundesbank's monthly balance sheet statistics. It should be noted the brackets are filled according to the initial time to maturity.

To keep things simple, we make the following assumptions when calculating the modified duration $\overline{D_{mod}(M_1, M_2)}$ for a specific position and maturity bracket with the boundaries M_1 and M_2: (i) the initial time to maturity is equally distributed between the boundaries; (ii) the bank has revolvingly invested the same amount in bonds with maturity M where $M_1 < M < M_2$; (iii) all bonds are default-free and continuously pay par yield r_f.

Table B.1: Initial maturities of lender and borrower clienteles

Position	1st bracket	2nd bracket	3rd bracket	4th bracket
Assets				
Loans to banks	daily	≤ 1 y.	> 1 y. ≤ 5 y.	> 5 y.
Loans to non-banks	≤ 1 y.	> 1 y. ≤ 5 y.	> 5 y.	
Bonds held	≤ 1 y.	> 1 y. ≤ 2 y.	> 2 y.	
Liabilities				
Loans from banks	daily	≤ 1 y.	> 1 y. ≤ 2 y.	> 2 y.
Loans from non-banks	daily	≤ 1 y.	> 1 y. ≤ 2 y.	> 2 y.
Subordinated debt		no maturity breakdown		
Saving accounts	≤ 3 m.	> 3 m.		
Bonds issued	≤ 1 y.	> 1 y. ≤ 2 y.	> 2 y.	

Maturity brackets reported in the Deutsche Bundesbank's monthly balance sheet statistics for different asset and liability classes.

The modified duration of a continuously par-yield-paying, default-free bond of maturity M is:

$$D_{mod}(M) = \frac{1}{r_f}\left(1 - \exp(-r_f M)\right). \tag{B.0.1}$$

The modified duration of a portfolio revolvingly investing in such bonds of maturity M, i.e. where the residual maturity is equally distributed within the interval $[0, M]$, can be expressed as (see also the Appendix of Memmel, 2011):

$$\begin{aligned}\overline{D_{mod}(M)} &= \int_{t=0}^{M} \frac{1}{M} D_{mod}(N) dN \\ &= \frac{M - 1/r_f\left(1 - \exp(-r_f M)\right)}{M r_f}.\end{aligned} \tag{B.0.2}$$

Finally, the modified duration of revolvingly investing in a portfolio of the aforementioned type of bonds of a given maturity bracket from M_1 to M_2, with initial maturity being equally distributed between the boundaries, is:

$$\overline{D_{mod}(M_1, M_2)} = \frac{1}{M_2 - M_1} \int_{M_1}^{M_2} \overline{D_{mod}(M)} dM. \tag{B.0.3}$$

Using first-order Taylor series approximations around $r_f = 0$, equation (B.0.2) yields:

$$\overline{D_{mod}(M)} \approx \frac{1}{2}M - \frac{1}{6}M^2 r_f, \tag{B.0.4}$$

and equation (B.0.3)

$$\overline{D_{mod}(M_1, M_2)} \approx \frac{1}{4}\left(M_2 + M_1\right) - \frac{1}{18}\left(M_2^2 + M_1^2 + M_2 \cdot M_1\right) r_f. \tag{B.0.5}$$

The asset's (liability's) modified duration D^A_{mod} (D^L_{mod}) is calculated using equations (B.0.4) and (B.0.5) employing weighted sums of all the brackets of assets (liabilities) reported in Table B.1. The weights correspond to the proportion of assets (liabilities) in a given bracket relative to total interest-bearing assets (liabilities). The modified duration gap is derived as

$$D_{gap} = D^A_{mod} - D^L_{mod} \frac{\textit{total interest-earning liabilities}}{\textit{total interest-paying assets}}. \tag{B.0.6}$$

When no upper boundary for a maturity bracket is reported, it is assumed to be 8 years. For saving accounts, applying legal maturities of 3 and 6 months would clearly overestimate the duration gap. Therefore, we assume 50% of the volume to be core deposits with long-term maturities of 9.5 and 10 years (depending on the legal maturity), and the other half is assigned its legal maturity (see also Purnanandam, 2007).

Appendix C

Revolving portfolios

The strategy of revolving portfolios is illustrated using an example. Imagine a bank that grants solely risk-free loans of five years maturity. Whenever a loan becomes due, a new loan with five years of maturity is granted. Under the assumption of time-invariant business, the residual maturity of the bonds in the bank's portfolio is equally distributed between zero and five years. Memmel (2008) shows that this bank's interest income margin is equal to the five-year moving average of five-year risk-free par-yield bonds. For balance sheet positions with a predetermined repricing period (like loans), the calculation is relatively straight-forward. For other positions, we chose the following assumptions:

- When no upper boundary for a maturity bracket is reported, it is assumed to be 8 years.
- Daily maturities are modeled using the 3-month government par yields in order to reduce the volatility resulting from estimation errors in fitting the lower end of the Svensson term structure.
- Savings deposits are modeled as 50% core deposits (see also Purnanandam, 2007). Deposits with up to 3 month maturities are modeled as the equally weighted moving average of the 3-month and 9.5-year par yields, deposits with longer maturities as the 6-month and 10-year par yield. Modelling savings deposits as weighted sums of moving averages of long and short-term interest rates is a methodology consistent

with the internal IRR management approaches of smaller German banks (see also Memmel, 2011).

Chapter 4

Market Timing, Maturity Mismatch, and Risk Management: Evidence from the Banking Industry*

Abstract

We investigate financial intermediaries' interest rate risk management as the simultaneous decision to manage on-balance-sheet exposure and to use interest rate swaps. Both decisions are substitute risk management strategies. For banks with trading activity, the maturity gap and the decision to use interest rate swaps are exogenous to one another. For banks without trading activity, the decision to use interest rate swaps is exogenous to the maturity gap, but the reverse relationship is endogenous. The magnitude of the maturity mismatch is, however, always an endogenous determinant of the extent of derivatives use. These findings provide support for the maturity gap being largely determined by customer liquidity needs, whereas the decision to use interest rate swaps relies on compliance with interest rate risk regulation. Exploiting the time-series variation in panel data, we find selective hedging behavior in the use of interest rate swaps driven by the slope of the yield curve as well as by funding uncertainty.

* This chapter is based on the working paper *Market Timing, Maturity Mismatch, and Risk Management: Evidence from the Banking Industry* by Ruprecht et al. (2013).

4.1 Introduction

Through their function as qualitative asset transformers, financial intermediaries are exposed to non-diversifiable risks, specifically liquidity and interest rate risk. Financial intermediation theory has derived models that explain the management and allocation of these risks. Among the seminal studies explicitly related to interest rate risk (IRR), Diamond (1984) stresses that banks should focus on managing credit risk for which they possess a monitoring advantage, and hedge all IRR. Hellwig (1994) suggests that banks allocate IRR to their depositors by offering contracts that do not necessarily repay deposits at par, thereby focusing on the liquidity risk of deposit withdrawal. Froot and Stein (1998) propose that banks hedge all risks that can be sold to the capital market at fair conditions, especially interest rate and currency risks.

However, empirical evidence contradicts financial intermediation theory to a large extent, as we observe a large fraction of smaller banks, in particular, that do not use any off-balance-sheet (OBS) IRR derivatives. Therefore, the question arises as to what determines banks' risk management decisions. As risks cannot be hedged only by means of OBS derivatives, but also by adjusting on-balance-sheet operating policies (e.g., Purnanandam, 2007; Hankins, 2011), banks that manage risk solely on-balance may simply pursue more conservative business strategies.

The most obvious reason for banks to keep IRR on the balance sheet instead of hedging it — for example, by using interest rate swaps — is the profitability of maturity or term transformation, which we will use interchangeably. A steep normally shaped yield curve increases profits when a bank operates with a positive maturity mismatch, i.e. its assets have longer maturities and reprice less frequently than its liabilities.[19] However, these profits are associated with the risk that a rise in the yield curve, especially at the lower maturity rates, may generate losses as in the savings and loan (S&L) crisis of the 1980s and early 1990s in the U.S. Moreover, the close alignment of interest and liquidity risk through the maturity mismatch can threaten banks' existence when they rely too heavily on short-term wholesale funding, as the 2007-2008 financial crisis showed quite plainly.

One central determinant of the decision to manage risk on the balance sheet or off it is the financial environment in which a bank operates. Allen and Santomero (2001) stress that banks' risk management techniques will differ between market-based and bank-based financial systems as a result of the degree of competition financial intermediaries face from financial markets. In bank-based economies, like Germany, financial intermediaries apply intertemporal smoothing of non-diversifiable risks through the accumulation of liquid reserves. In market-based economies, households will withdraw their funds when banks build up liquidity reserves. Financial intermediaries need different, cross-sectional risk management strategies to shield themselves and households' portfolios against the aforementioned risks (Allen and Gale, 1997). Increasingly popular cross-sectional risk sharing encompasses derivatives hedging.

In spite of banks' importance as suppliers of external capital and the IRR related to their activities, the literature on banks' IRR management is relatively scarce, whereas the majority of risk management literature focuses on corporate hedging decisions, mainly

[19] Memmel (2011) estimates the income from term transformation generated by German savings and cooperative banks over the business cycle to be around 30 basis points annually, which is a significant share of their overall interest income.

commodity price hedging. Among the few exemptions, Schrand and Unal (1998) examine thrifts' overall risk management and find — in line with the models of Diamond (1984) and Froot and Stein (1998) — a shift from interest rate risk towards credit risk following thrift conversion. These authors suggest that risk management is a mean of allocating risks from homogeneous risk sources, such as IRR, to core-business risks, where the bank possesses a comparative information advantage.

Smith and Stulz (1985) show that hedging reduces cash flow variability and consequently diminishes bankruptcy risk. Froot et al. (1993) endogenize the cost of financial distress by assuming external capital to be more expensive than internally generated funds. In support of these models, Brewer et al. (1996) show that hedging IRR reduces the cost of uninsured debt, i.e. rates paid on commercial paper issued by thrifts. Purnanandam (2007) simultaneously investigates the use of derivatives for hedging purposes and on-balance-sheet IRR management of the duration gap for U.S. commercial banks. He finds that banks intensify IRR management in response to increasing default risk. Additionally, the use of interest rate derivatives makes banks less vulnerable to monetary shocks and allows them to change the composition of their portfolios less drastically. Memmel and Schertler (2011) show for the same sample of German commercial banks we also investigate that net interest income is more heavily affected by changes in the yield curve than by changes in the composition of asset and liability portfolios. Banks that use IRR derivatives are less vulnerable to interest rate shocks, and hence derivatives are mainly employed for hedging purposes. However, when the yield curve steepens derivative users increase their maturity mismatch more significantly.

Bolton et al. (2013) present a dynamic risk management model where bankruptcy risk increases the risk of not having sufficient funds for value-adding investment projects, thus increasing the incentives to hedge. However, for financially constrained firms it is optimal not to hedge as margin requirements override cash flow volatility concerns. Moreover, their model shows that *market timing* behavior can be rational in terms of ensuring sufficient funding sources.[20]

Market timing of risk management activities has received increasing attention in financial research. Stulz (1996) defines *selective hedging* as managers incorporating market views into the timing of risk management activities, and considers this a mild form of *speculation*. Empirical and survey evidence from non-financial firms suggests that timing derivatives markets is done quite frequently. Such strategies should, however, result in permanent additional profits only if managers have an information advantage, but sum up to zero if not.

The main drivers of selective IRR risk management when entering into new debt contracts or interest rate derivatives are the level and, especially, the slope of the yield curve. Faulkender (2005) finds that firms alter the IRR exposure of new debt issues from fixed to floating by jointly entering into interest rate swaps when the yield curve is steep. Vickery (2008) confirms these results for small bank-dependent firms that choose between fixed-rate and variable-rate loans. Credit constrained firms, however, are more likely to choose fixed-rate interest per se. Recently, Mian and Santos (2012) have found evidence of active maturity management driven by liquidity considerations. Credit-worthy firms tend to

[20] The model of Bolton et al. (2013), however, incorporates equity market timing through the issuance of new shares, and not debt market or derivatives market timing.

renegotiate and extend loan maturity early during periods of good financial conditions. The behavior of bank-dependent borrowers should have a directly observable effect on banks' balance sheets and might trigger changes in their OBS risk management. Besides selective hedging, corporate use of interest rate derivatives also reveals *speculation* on interest movements. Géczy et al. (2007) and Chernenko and Faulkender (2011) find evidence that financially unconstrained firms incorporate market views into their derivatives positions and use interest rate swaps, at least partly, for speculative purposes, too.

We investigate German commercial banks' IRR management between 2000 and 2011 by simultaneously estimating their maturity mismatch and interest rate swap activities. Our empirical approach combines the simultaneous risk management framework of Purnanandam (2007) with the cross-sectional and time-series regression models of Chernenko and Faulkender (2011) to distinguish the use of interest rate swaps for hedging and speculative purposes in panel data. On-balance-sheet IRR management and the use of interest rate swaps are substitutes for one another in pursuit of the goal of keeping the overall IRR exposure below regulatory thresholds. This confirms the results recently found by Hankins (2011) that operative and financial hedging are substitutes in an attempt to manage banks' overall risk exposure. We also give evidence of hedging theories which predict that the cost of bankruptcy makes firms pursue more conservative risk management. Selective market timing behavior is observed for the maturity mismatch, the decision to use interest rate swaps and the extent of their use with regard to the slope of the yield curve and interbank funding uncertainty. The profitability of a steep yield curve induces commercial banks to simultaneously increase their duration gap and to hold fewer interest rate swaps for hedging purposes, while the opposite holds for increasing funding uncertainty as measured by a spread of the LIBOR over the government bond yield.

In all risk management equations, we use two exogenous instruments for the endogenous variables in the simultaneous equations framework. We prove the instruments' relevance and validity not only to justify inference in the risk management regressions but also for the proper use of Hausman-type tests on the exogeneity of the instrumented variables (Hahn et al., 2011). These tests give evidence that, for banks with a trading book, both the maturity gap and the decision to use interest rate swaps are exogenous to one another. For banks without a trading book, the decision to hedge is exogenous to the maturity gap, but the reverse relationship is endogenous. Only in samples of banks that use interest rate swaps for the first time are these variables both endogenous to one another. On the other hand, the maturity gap is always an endogenous driver of the extent of banks' swap holdings. These results clearly reflect the impact IRR regulation has on bank behavior. Banks with too high an IRR exposure after netting out the OBS effects are considered "outlier" banks that can expect supervisory scrutiny and even additional capital charges. Hence, once the on-balance-sheet IRR exposure becomes too large, a bank has to look for ways to decrease the overall exposure and will likely do so using interest rate swaps. Only in these circumstances, the maturity gap and the decision to hedge are endogenous to one another. Before a bank reaches the critical threshold for on-balance-sheet exposure or once it has set up a derivative risk management department, the decision to use interest rate swaps is exogenous. As banks that have a comparatively large duration gap are those that decide to use interest rate swaps, the duration gap is an endogenous driver of the volume of swaps held. This implies that banks manage their overall exposure to comply with the IRR regulation, whereas the maturity gap is determined by the liquidity needs of bank-dependent borrowers and depositors.

The paper proceeds as follows. Section 4.2 describes the empirical research strategy and puts emphasis on the instruments used to identify the system of equations in the IRR framework. Data and summary statistics are presented in Section 4.3, before we proceed with the empirical analysis. Section 4.4 introduces the hazard rate model which is estimated in order to derive proxies for the cost of default in the risk management analysis. Section 4.5 presents the results for the simultaneous equations of the IRR management decisions, i.e. the on-balance-sheet exposure measured as the duration gap, the decision to use swaps and the extent of interest rate swap use. Whenever possible, regressions are run both cross-sectional and based on time-series estimators. The paper ends with concluding remarks in Section 4.6.

4.2 Research Design

4.2.1 Regressions and Variables

Following Purnanandam (2007), we estimate both the maturity mismatch and the swap use decision simultaneously in a system of equations. In line with most of the risk management literature, we estimate a Cragg (1971) model and separate the decision to hedge from the extent of derivative use (e.g., Purnanandam, 2007; Zhu, 2012). The decision to hedge corresponds to a dummy variable that takes the value of 1 if a given bank reports a non-zero volume of interest rate swaps outstanding. The degree of hedging is modeled as the natural logarithm of the nominal volume of interest rate swaps outstanding to total assets. To control for the potential sample selection bias arising from taking the logarithm of the nominal swap volume, we include the inverse Mills ratio. The modified duration gap is modeled using information available to the banking supervisors on different brackets of remaining time to maturity for classes of assets and liabilities and the interest rate sensitivities from the standard approach for IRR regulation of the German banking supervisory authority BaFin. See Appendix E, for more details of the modified duration gap.

We exploit both the cross-sectional and the time-series variation in panel data ranging from 2000-2011. Cross-sectional variation in linear models is captured applying both between effects and Fama-MacBeth estimators. The results are then compared with pooled OLS models to evaluate the impact of potential bias. Time-series variation is investigated applying the within transformation of a fixed effects estimator. Just for models of the decision to use swaps, we apply pooled probit regressions only in order not to lose observations on banks that never hedge or, alternatively, hedge during the whole sample period.

The use of cross-sectional as well as time-series estimators for IRR management decisions, such as the on-balance-sheet exposure and the extent of interest rate swap, is related to the empirical approach of Chernenko and Faulkender (2011) who examine non-financial firms' interest rate swap use. One of the key elements of interpreting the coefficients is that these firms are assumed to have a constant exposure to IRR over time. When firms manage towards a target fixed-to-floating IRR exposure, average hedge ratios should be explained by between effects and Fama-MacBeth models. In contrast, deviations from a target hedge ratio over time can be regarded as market views on IRR drivers incorporated into the hedging decision. Such market timing is then captured by fixed effects estimators.

Although the assumption of a constant IRR exposure over time is doubtful for banks, there is nevertheless evidence that banks focusing on providing financial intermediation services to local market retail customers have a comparably stable on-balance-sheet exposure. In Germany, especially the smaller, locally operating savings and cooperative banks have stable, homogeneous business models with a focus on granting loans and accepting deposits. Under the assumptions that a bank's on-balance-sheet maturity structure remains stable through replacement of maturing assets and liabilities with new business of the same initial maturity, and that business volumes have been generated in a way which is equally distributed over time, a bank's interest income and expenses can be modeled using portfolios of revolving investments in par-yield paying bonds.[21] Memmel (2008) and Entrop et al. (2012) apply this approach empirically to German commercial banks' interest income and expenses since 1998 and can explain most of the variation in these, especially for the smaller banks, giving support to the empirical validity of the assumptions.[22] The results of Memmel and Schertler (2011) give further support that the on-balance-sheet exposure is comparatively stable among German banks.

These small commercial banks are also more likely not to engage in trading activities, and fee income is a less important source of profitability. Most of them only have a banking

[21] See Memmel (2008) for a detailed introduction to this approach.

[22] A very simplified approach using revolving portfolios is even able to capture the general time-series dynamics of German banks' overall interest exposure, after netting on- and off-balance-sheet positions (Memmel, 2011).

book and no trading book. Pure banking book institutions are not only more likely to have a stable on-balance-sheet exposure but are also prohibited from using OBS interest rate instruments for speculation purposes to a substantial extent.[23]

In analyzing only pure banking book institutions, we thus have a similar setting to Chernenko and Faulkender (2011). In order to examine the whole German banking sector, we run regressions for the total sample, which consists of around 90% non-banking book institutions, and on the sub-sample of trading book banks. The latter not only have more exposure to market risk, they may also use interest rate swaps for speculation which goes beyond the market timing of risk management activities. Empirically, trading revenues are often found to be the riskier source of income (e.g., Stiroh, 2004) and establishing a trading book might result in risk shifting from traditional relationship banking to trading (Boot and Ratnovski, 2012).

In our empirical study, we investigate the impact of on-balance-sheet IRR, captured in the modified duration gap, on the decision to use interest rate swaps and vice versa, and therefore estimate our model as a system of three simultaneous equations. The third equation analyzes the extent of swap use and includes the duration gap as an explanatory variable. Our bank-specific explanatory variables are consistent with those used in the study by Purnanandam (2007). As corporate risk management theory stresses the importance of the cost of bankruptcy for risk taking, hedging and speculation behavior,

[23] The German Banking Act (*KWG*) defines banks as trading book institutions when they have on average (in a single year) either trading activities of more than 5% (6%) in relation to both total assets and off-balance-sheet activities, or of more than €15 (20) million in absolute terms. These volumes are minor compared to the total assets of commercial banks in Germany, even of the small cooperative banks. See Table 4.2 for details.

we include the natural logarithm of the *Probability of default* (PD) derived from a hazard rate model to proxy for this determinant. *Size*, measured as the logarithm of total assets, is included to proxy for economies of scale in setting up a derivatives department. Larger banks are more likely to have a risk management department that is proficient enough to deal with derivatives. At the same time, larger banks are also more likely to have other income sources apart from interest income and might, as a result, not depend to the same extent on income from term transformation. Based on Froot et al. (1993) banks with more investment opportunities should be more likely to decrease IRR, both on balance sheet and off balance sheet. Investment opportunities are proxied in line with the banking literature (e.g., Froot and Stein, 1998) as the (annual) *Total asset growth* rate. As current risk management literature stresses the importance of liquidity management considerations, we include two measures which capture liquidity on the asset and liability side, *Liquid assets*, the sum of cash reserves and securities which can be sold within one year, and the ratio of *Savings deposits* to total assets as a measure of funding strength.

In addition to Purnanandam, we include a *Branch HHI*, a Herfindahl (-Hirschman) index of branch concentration at the county level, as a measure of bank competition. Most of the savings banks and cooperative banks, and, therefore, the majority of banks in our sample, are limited to running branches in their municipality, which is referred to as the regional principle. We therefore consider the county level the relevant market to measure banking concentration, although merger activity has now created some savings banks and cooperative banks with a territory exceeding a single county and even though private banks were never limited to the regional principle. The model derived by Adam et al. (2007) predicts that competition has a direct impact on the decision to hedge risks in equilibrium. Furthermore, competition may have an effect on the maturity mismatch choice via its nexus with risk taking. When we investigate the total sample, we also include a dummy that takes the value of 1 for banks with a *trading book*, and we include banking group dummies (savings, cooperative and private commercial banks) to control for different business models in the cross-sectional settings. Time-series models of the maturity gap and the extent of interest rate swap use as well as the pooled probit models of the decision to use interest rate swaps also include macroeconomic variables to test for market timing behavior in IRR management. These include the slope of the yield curve (e.g., Faulkender, 2005; Vickery, 2008) and a variable we refer to as *LIBOR spread*, the difference between the 12-month LIBOR and the German government bond yield. The latter is intended to capture the effects of the TED spread used in U.S. banking studies and proxies for interbank funding uncertainty. We also interact both of the aforementioned macroeconomic variables with the 1-year government bond yield to analyze differing effects of banks' risk taking behavior in response to the monetary environment (Borio and Zhu, 2012).[24]

When analyzing banks' internally calculated overall IRR exposure after netting on and off-balance-sheet exposures, Memmel (2011) finds that regulatory screening and time effects only explain a minor share in the variation of IRR exposure. The majority of variation is due to bank-specific, idiosyncratic effects. With our regression setting, we not only shed light on the drivers of these idiosyncratic effects, but also distinguish between their effects on on-balance-sheet and off-balance-sheet risk management.

[24] For an overview of the variables used in the empirical study, including those in the hazard rate model, see Appendix D.

4.2.2 Identification Strategy: Exclusion Restrictions

We expect the maturity mismatch and the decisions to use interest rate swaps and the extent of their use to be jointly determined as banks manage their overall IRR exposure. The strict exogeneity assumption of an OLS estimator is then violated and the derived coefficients are biased. A strategy to overcome this violation is an instrumental variable (IV) estimation. Valid IVs are only allowed to influence one of the two risk management decisions, either the on-balance-sheet or the off-balance-sheet decision, but not to have a direct impact on the other decision, which is referred to as the exclusion restriction. Having more than one IV for each endogenous variable, we can statistically test validity via an overidentification test. With strong as well as valid instruments at hand, we test the endogeneity assumed in the simultaneous equation framework, using a Durbin-Wu-Hausman type specification test (Hahn et al., 2011).

We will use the following instruments in the risk management equations. For the duration gap, we propose the use of the share of *Customer loans* in relation to total assets and *Loan commitments* to total assets. For the decision to use interest rate swaps and their extent we include *Past swap experience* as a dummy variable that is 1 when a bank has once used a swap, both interest and/or currency swaps, since 1998. We additionally use *Average board experience*, as the average experience of all board members in relevant executive management positions measured in years, as an instrument for the decision to use interest rate swaps but not for their extent. This allows us to correct for the sample selection bias by adding the inverse Mills ratio into the extent of interest rate swap regressions. Furthermore, we include an exogenous instrument with regard to the risk management decisions in the estimation of the hazard rate model. Here, we choose *Hidden liabilities*, a dummy variable that takes the value of 1 when a bank avoids writing off assets by making use of an accounting option. Below, we justify the use of these specific IVs.

Instruments to identify the probability of default:

Risk management theory postulates that the cost of bankruptcy and the resulting financial constraints are an endogenous determinant of risk management decisions. Although the variables we use in the hazard rate model are not identical to those in the risk management analysis, many of the variables that explain a bank's default are also drivers of its risk management decisions. Hence, these variables do not qualify as IVs.

In order for the PD derived from the hazard rate model to be an exogenous determinant of the IRR management decisions, at least one explanatory variable must not have a direct influence on the magnitude of the duration gap, the decision to use swaps, and the extent of their use. We argue that avoiding write-offs on assets,[25] — creating so called *Hidden liabilities* — satisfies the exclusion restriction. This accounting option in the German GAAP — (the commercial code, *HGB*) — is often used as a form of "window dressing" for accounting statements by postponing realized losses into the future.

Biddle et al. (2012a) observe that accounting conservatism[26] reduces subsequent corporate bankruptcy risk through restricted earnings management and higher cash reserves. Moreover, Biddle et al. (2012b) find that accounting conservatism directly reduces distress

[25] Write-offs can be avoided by assigning and reclassifying certain kinds of securities to the banking book, where they are accounted for at historical cost instead of their lower market value.

[26] Accounting conservatism is considered to be a prudent reaction to risk and uncertainty and their adequate disclosure in accounting statements.

likelihood by reducing operating cash flow downside risk, consistent with the theoretical model of Froot et al. (1993). It has an additional indirect effect through higher cash holdings. Distinguishing between conditional and unconditional conservatism,[27] it is found that conditional accounting conservatism serves as a complementary strategy, whereas unconditional accounting conservatism serves as a substitute strategy for traditional risk management, such as cash management, operative and derivatives hedging. Avoiding hidden liabilities and thereby realizing losses on securities held in a more timely manner is a form of conservative accounting. After controlling for the indirect effect accounting conservatism has on cash holdings, by controlling for liquid assets in the risk management decisions, there should be no effect of hidden liabilities other than through operating cash flow downside risk which is captured in our measures of the distress likelihood.

Instruments to identify the maturity gap equation:

The maturity gap, especially for the small, savings and cooperative banks, is driven by the demand for long maturity liquidity on the asset side and the supply of short-term deposits on the liability side. In contrast, interbank loans are used by the smaller savings and cooperative banks to reduce the on-balance-sheet exposure (Ehrmann and Worms, 2004). Instrument validity is given when the *Customer loans* have no direct effect on interest rate swap use except through the (expected positive) effect on the magnitude on the maturity gap.

We argue that the only effect *Loan commitments* have on interest rate swap usage is through their on-balance-sheet effect on the maturity mismatch. This argument seems

[27] Unconditional conservatism is the effect of accounting principles per se. Conditional conservatism relates to more timely recognition of negative corporate outcomes.

counterintuitive as the fixed-rate loan commitments prevailing in Germany inherit IRR that can (partly) be hedged using derivatives. Additionally, as loan commitments are OBS activities, they do not have a directly observable impact on the on-balance-sheet IRR.

Besides econometric evidence from overidentification tests, we give further evidence of the exogeneity of loan commitments by drawing on the literature. Although our duration gap proxy captures the bank's sensitivity to changes in interest rates, the measure is also closely related to a bank's liquidity risk exposure. Kashyap et al. (2002) derive a model in which banks possess a natural hedge against liquidity risk via imperfectly correlated draw-down risk for loan commitments and withdrawal risk for deposits. Carrying out both lending and deposit activities offers banks synergies in using the buffer stock of liquid assets.

Berrospide et al. (2012) investigate corporate use of credit lines and find that U.S. firms that hedge the IRR from variable-rate loan commitments using interest rate swaps may draw on their credit lines more heavily. The liquidity risk in loan commitments seems to be considered more important compared to the IRR. It should be noted that floating-rate loan commitments — as typically offered in the U.S. — expose borrowers to IRR, whereas fixed-rate commitments — as prevailing in Germany — expose the financial intermediary.

A further link between loan commitments and the maturity of loans is put forward by Berger et al. (2005), who find that corporates that draw loans under commitment receive loans with no different maturity if they are high-risk firms. On the other hand, high-risk corporates that do not draw under commitment receive only loans with significantly lower maturity. Loan commitments, especially (revolving) lines of credit, are a means of acquiring soft information on borrowers out of relationship lending[28] and provide monitored liquidity insurance that prevents borrowers' illiquidity seeking (Acharya et al., 2012). Therefore, undrawn loan commitments can already have a direct effect on the existing maturity gap via the information collected from relationship lending and via intensified monitoring upon frequent renewal.

We do not claim that fixed-rate loan commitments do not carry any IRR that can be hedged using interest rate swaps, but argue that liquidity risk is the prevailing risk in loan commitments. After controlling for asset and funding liquidity, loan commitments should not have any influence on either the decision to use swaps or the extent of their use; however they still have an effect on the maturity mismatch.

Instruments to identify the swap use decision and the extent of their use equations:

The *Past swap experience* dummy serves as a proxy for the existence of a derivatives risk management department or experience in handling interest rate derivatives. Chen (2011) uses a similar instrument; specifically, the past experience of fund managers as an IV for the current use of derivatives by the hedge funds they manage. Purnanandam (2007) uses a cross-sectional hedging experience dummy that takes the value of 1 if the bank holds derivatives for purposes other than IRR management during the same period. Unfortunately, in our sample too few banks use currency swaps to create IVs that pass the weak identification test.[29]

[28] See, for example, Berger and Udell (1995); Jiménez et al. (2009); Norden and Weber (2010), and specifically for German banks screening for bankruptcy risk, Davydenko and Franks (2008).

[29] We run robustness checks, not reported for brevity, that contain information on whether the bank uses any kind of derivatives to hedge or speculate on currency or market risk. Unfortunately, data is

One potential concern with a dummy based on past hedging experience is that previous years' interest rate swap use predetermines contemporaneous use. This would be the case if a bank buys swaps with maturities of more than one year and holds them until maturity. We do not see a problem in using past swap use for the following reasons. First, about 10% of the banks in our sample that used swaps in an earlier year, do not do so the year after. Therefore, swap experience does not perfectly predict current swap use and some banks change frequently between years where they use swaps and years where they do not. Even if banks engage in swaps with maturities of more than one year, it is possible for them to close these positions. Second, Gorton and Rosen (1995) report that a substantial share of interest rate swaps held by banks have maturities of less than one year for reasons of regulatory capital charges on counterparty risk. Moreover, during the past decade, there has been a substantial increase in short-term maturity overnight index swaps (OIS) to hedge interbank rates. Current figures presented by Fleming et al. (2012) support these statements. Although 10-year and 30-year interest rate swaps are still frequently traded tenors for hedging the IRR from long-term loans, the vast majority of all interest rate derivatives have maturities of less than one-year.

Our second instrument is based on the finding that characteristics of board members have an impact on hedging decisions, but not on the extent of hedging (e.g., Zhu, 2011, 2012). Therefore, we include the average experience of all board members in bank executive

available only until 2008. The coefficients derived are very similar to those reported when employing the *Past swap experience* and overidentification tests are also insignificant for all samples investigated. However, the weak instrument statistics are significantly lower, and although they are still above the values suggested by Stock and Yogo (2005), the coefficients for the instrumented *Dummy interest rate swap use* cannot be distinguished from zero.

positions measured in years as an explanatory variable for the decision to use swaps. As this variable does not influence the extent of hedging, we can use it additionally to estimate the *Inverse Mills ratio* in a sample selection model and do not simply identify the selection model from the non-linearity of a probit estimator. Average board experience therefore qualifies the exclusion restrictions for both the maturity gap and the extent of swap use decision and only has a direct impact on the decision to use interest rate swaps. Zhu (2011) uses a dummy based on whether the CEO is below the age of 45 as a variable identifying the decision to hedge, but not the extent thereof.[30] We argue that board experience has no other influence on the maturity gap decision apart from the effect through the use of interest rate derivatives, as the maturity gap for most banks is largely determined by borrower and depositor liquidity needs.

In summary, we estimate the following system of equations:

$$\begin{aligned} DG =& \alpha_{DG} + \beta_{DG1} SU + \beta_{DG2} CL + \beta_{DG3} LC + \beta_{DG4} X + \epsilon_{DG} \\ SU =& \alpha_{SU} + \beta_{SU1} DG + \beta_{SU2} PSE + \beta_{SU3} BExp + \beta_{SU4} X + \epsilon_{SU} \\ SE =& \alpha_{SE} + \beta_{SE1} DG + \beta_{SE2} PSE + \beta_{SE3} IMR + \beta_{SE4} X + \epsilon_{SE}, \end{aligned} \tag{4.2.1}$$

where, for simplicity subscripts indicating bank or time units are left out. DG stands for the (modified) duration gap, SU for a dummy of the swap use decision, and SE represents the extent of interest rate swap use, proxied as the logarithm of the nominal volume of interest rate swaps in relation to total assets. CL is customer loans, and LC loan commitments. PSE is the dummy of past interest rate swap experience, and $BExp$

[30] For the smaller German savings banks and cooperative banks, it is not possible to identify the CEO or the CFO of a bank as these banks do not distinguish between different board responsibilities.

the average board experience, while IMR is the Inverse Mills ratio controlling for sample selection in the extent of interest rate swap use. X is a vector of all exogenous explanatory variables that influence all risk management decisions.

4.3 Data and Summary Statistics

Data

We use data from 2000-2011 in our simultaneous risk management framework. The start date of the analysis is due to the availability of data for the variable *Liquid assets*. For the hazard rate model we employ data starting in 1994 to make use of as many default events as possible, especially restructuring mergers during the wave of consolidation, the German banking sector underwent in the 1990s. To create the instrument *Past swap experience*, we use information dating back to 1998. All data is provided by the prudential banking supervision databases of the Deutsche Bundesbank. The data is taken from the P&L and balance sheet statements, the auditor's report, year end values of the monthly balance sheet statistics, and liquidity reporting. Macroeconomic data is identical to that available on the Bundesbank's website. Board experience is taken from a supervisory database on characteristics of bank managers in executive positions, as the appointment to such a position has to be approved by the German banking supervisory authority BaFin. Default data comes from a database on regulatory interventions.

We windsorize our variables at the 99th percentile and at the 1st percentile, except for Size and (the logarithm of) the Probability of default estimated in the hazard rate model. The impact of mergers on the consistency of accounting measures is accounted for by creating a new “artificial” banking entity after every merger taking place. This is the most frequently applied approach when using Bundesbank data. When we create the *Past swap experience* dummy, the variable takes the value of 1 for the new entity if at least one of the two pre-merger institutions used any kind of swaps before the merger. As our variable is intended to proxy for the existence of a derivatives risk management department, this procedure seems justified as the knowledge of how to hedge risks off the balance sheet is unlikely to be lost during a merger process.

Summary Statistics

Table 4.1 displays the distribution of banks using interest rate swaps over the sample period from 2000-2011. Although the absolute number of banks reporting interest rate swap use increases only slightly from 640 to 678, their relative share increases heavily from 29.95% in 2000 to 49.16% in 2011. This effect is due to the consolidation of the German banking sector that led to the disappearance of about 700 banks during the sample period. The relative increase in the use of interest rate swaps was quite sharp between 2000 and 2007, but slowed thereafter. A clear relation between a bank’s size and the use of interest rate swaps is observable. Whereas in the lowest size quintile, less than 13% of banks hold interest rate swaps, the percentage increases gradually and peaks at the highest quintile at more than 83%.

Interestingly, the current share of interest rate swap users is close the 50%, which is the solution of firms hedging in equilibrium in the Adam et al. (2007) model. These authors also summarize many studies which find the percentage of non-financial firms in several industries and indices to be close to this value. As the banking sector is a

Table 4.1: Distribution of Swap Users over Time

				Size Quintiles				
Year	Total no. banks	No. Swap Users	in %	1st	2nd	3rd	4th	5th
2000	2,048	640	29.25	10.82	27.97	41.13	45.57	66.54
2001	1,902	601	29.07	7.74	26.20	39.35	45.75	70.61
2002	1,784	572	29.60	6.54	25.32	37.60	47.04	71.28
2003	1,659	546	31.28	7.69	25.63	39.15	47.26	72.08
2004	1,646	595	34.99	8.21	29.08	39.08	50.46	73.01
2005	1,597	593	36.13	8.26	28.21	38.42	55.35	75.00
2006	1,579	682	42.37	8.79	35.90	45.60	59.56	77.78
2007	1,548	715	45.87	10.59	38.10	49.72	62.86	78.59
2008	1,494	702	46.92	10.44	33.62	50.71	62.96	80.24
2009	1,446	684	47.16	11.59	32.19	46.43	64.24	83.04
2010	1,442	685	47.30	12.14	30.29	46.42	60.26	82.18
2011	1,377	678	49.16	12.79	31.10	49.55	62.20	83.15
Total	19,522	7,693	38.28	10.02	29.31	42.63	53.39	75.69

This table presents descriptive statistics on 19,522 bank-year observations of German commercial banks between 2000-2011. Size quintiles are based on total assets in 2011, where the 1st quintile encompasses the smallest and the 5th the largest banks. Swap users are defined according to a positive nominal volume of interest rate swaps at the end of a given calendar year. This table encompasses all commercial banks and is not limited to the data requirements of the samples used for the regression analysis.

regulated industry with supervision of risk management, this result should, however, not be mistaken for the industry equilibrium percentage of hedging firms in the model cited above.

Surprisingly, we find a significantly larger percentage of banks that manage IRR off the balance sheet in our study compared to Purnanandam (2007), although the theory of intertemporal smoothing would have predicted the opposite (Allen and Santomero, 2001). In our sample, 31.28% of commercial banks report interest rate swaps outstanding in 2003, whereas Purnanandam reports 5.94% users of interest rate derivatives for hedging purposes for his U.S. commercial bank sample in the third quarter of 2003.

We present summary statistics of the variables used in the risk management equations in Table 4.2 separately for interest rate swap users and non-users, and test for differences in means and medians between these two groups. Some noteworthy features appear: swap users have a slightly higher modified duration gap, but the economic magnitude of the difference is not too pronounced. The mean difference is only 0.14 percentage points, but significant at the 1% level. Moreover, swap users are larger in size with regard to total assets and are more likely to have a trading book. They hold less liquid assets and receive less funding from savings deposits, but nevertheless make more loan commitments. Interestingly, the average board experience is significantly lower for banks that use swaps. For most of the variables, the differences between users and non-users are significant at the 1% level. One exception is the difference in the means of the probability of default, which cannot be distinguished statistically.

German commercial banks indeed have comparatively large buffer stocks of liquid assets, as predicted by the theory of intertemporal smoothing in Allen and Gale (1997). The mean of liquid assets in relation to total assets is around 43.5% for swap users and 44.5% for non-users, and the difference of 1 percentage point is economically not very large, although statistically significant. Purnanandam (2007) reports non-users as having, on average, 36% and users 30.5% liquid assets. Here, overall levels are smaller and the difference between users and non-users of interest rate derivatives for hedging purposes is more pronounced. It should, however, be borne in mind that the definitions of liquid assets do not completely match.

4.4 Hazard Rate Model

Following Purnanandam (2007), we proxy for the cost of bankruptcy by estimating the bank-specific probability of default (PD) from a hazard rate model.[31] The hazard rate

[31] This approach implicitly assumes identical loss given default (LDG) for banks when the PD is the only relevant variable. Purnanandam (2007), however, finds no qualitatively different results when proxying LGD instead of PD. Moreover, the model of Brunnermeier and Oehmke (2012) implies that

Table 4.2: Summary Statistics

	Swap Users		Non-Swap Users		Group Differences		p-values	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Hazard Rate Model								
Capital ratio	5.107	4.982	5.765	5.424	-0.658	-0.442	0.000	0.000
Total reserves	1.741	1.661	1.796	1.611	-0.055	0.050	0.000	0.000
HHI credit portfolios	15.562	12.608	15.600	13.319	-0.038	-0.712	0.415	0.000
ROE	11.936	12.122	11.009	11.742	0.927	0.380	0.000	0.000
Dummy hidden liabilities	16.018	0.000	12.167	0.000	3.851	0.000	0.000	0.000
IRR Simultaneous Equations								
Modified duration gap	3.300	3.402	3.16	3.228	0.14	0.174	0.000	0.000
Probability of default	3.162	0.699	3.256	0.802	-0.094	-0.103	0.514	0.000
Total assets	6,112.57	900.648	1,257.88	221.936	4,854.69	678.712	0.000	0.000
Total asset growth	1.116	0.753	1.198	1.022	-0.082	-0.269	0.103	0.000
Savings deposits	13.065	12.070	15.449	14.564	-2.384	-2.494	0.000	0.000
Liquid assets	43.476	41.443	44.452	42.751	-0.976	-1.307	0.000	0.000
Loan commitments	0.687	0.477	0.614	0.450	0.073	0.027	0.000	0.000
Customer loans	57.403	59.21	58.422	59.811	-1.018	-0.601	0.000	0.000
Avg. board experience	11.601	11.000	13.63	13.000	-2.029	-2.000	0.000	0.000
Branch HHI	19.383	18.378	19.065	18.275	0.318	0.104	0.000	0.000
Dummy trading book	19.912	0.000	3.096	0.000	16.816	0.000	0.000	0.000

This table presents descriptive statistics on 19,336 bank-year observations of German commercial banks between 2000-2011. Total assets are in €millions. Avg. board experience is in years. All other variables are in percentage points. The p-value on mean differences is a two-sided t-test computed under the assumption of independence. The p-values of median differences are based on the Wilcoxon rank-sum test. The branch HHI can take values between 0 and 10,000.

model is estimated using default events from 1994 to 2011. As defaults appear on various dates during a given year, all covariates are lagged values from the previous year-end. Defaults for 2012 were not available at the start of this study. PDs for 2011 have therefore been predicted from the coefficients derived with covariates until 2010. We include the following default indicator dummies as the dependent variable: forced closures and restructuring mergers as well as capital injections by either sectoral insurance schemes or the federal scheme set up during the recent financial crisis. The model is estimated using a pooled multiperiod logit model (Shumway, 2001) with standard errors clustered at bank level. A similar model is used in the banking supervision department of the Bundesbank to gauge the financial soundness of national banks. The bank-specific covariates are based on the CAMELS taxonomy and therefore include variables capturing Capital adequacy, Asset quality, Management, Earnings, Liquidity, and Sensitivity to market risk.[32]

Specifically, we choose the following variables to estimate the PD: capital adequacy is included using the *Tier 1 capital ratio*, the ratio of tier 1 capital to risk-weighted assets (RWA), and *Total bank reserves*, the ratio of total banks reserves that serve as equity, to total assets (TA). The dummy *Reserve reduction* takes the value 1 if the aforementioned reserves have been reduced. Asset quality is proxied using a Herfindahl (-Hirschman) index (HHI) of loan concentration over 23 industry sectors. Earnings are captured by *ROE*, the return on equity, defined as operating income to equity. Additionally, the competitive

a bank's PD, and not the LGD, is the major driver of a "maturity rat race" leading to excessively short durations for banks' liabilities.

32 Liquid asset measures are not included as an explanatory variable, which is the common procedure in the "Bundesbank hazard rate model". If included, such measures show up insignificant as liquidity appears to be an indicator for the lack of business opportunities and not of active risk management (Porath, 2006).

environment is controlled for by the *Branch HHI* on the county level. Financial intermediation theory provides predictions for the nexus of risk taking and competition. Boyd and De Nicoló (2005) show that the effect of competition on bank risk taking depends on borrowers' reaction on the transmission channel of market power into loan rates. More concentrated banking markets can trigger less risk taking through rising charter values. However, raising loan rates can also increase risk taking when the pool of borrowers is more likely to default. Therefore, predictions on the coefficient of the *Branch HHI* cannot be made. The level of the short-term interbank *3-month LIBOR* rate and *regional GDP growth* at the state level are included to control for changes in the macroeconomic environment. Dummies for savings and cooperative banks capture heterogeneity in business models with private commercial banks being the reference group left out.

The impact of these variables can be seen in Table 4.3 and is presented displaying marginal effects from the logit model. As expected, Tier 1 capital and bank reserve endowments reduce bankruptcy risk significantly, whereas the dummy indicating reserve reductions is an indicator of significantly higher default likelihood. Specialization in certain business sectors via concentrated loan portfolios does not significantly impact default likelihoods. ROE significantly reduces bankruptcy risk through its effect on capital accumulation. A higher value for the Branch HHI indicates more concentrated and, therefore, less competitive banking markets. Our results thus indicate that competition in the banking market slightly improves banking stability. Business conditions captured in local GDP growth have no significant influence on bank default, but a lower level for short-term interbank rates increases distress likelihood as predicted by the risk-taking channel of monetary policy (Borio and Zhu, 2012). At first glance, this finding contradicts the effect that

Table 4.3: Hazard Rate Model

Capital ratio	-0.0382**	
	(0.016)	
Total reserves	-1.6612***	
	(0.138)	
Dummy reserve reduction	0.6270***	
	(0.115)	
HHI credit portfolios	-0.0062	
	(0.005)	
ROE	-0.0451***	
	(0.004)	
Branch HHI	0.0002**	
	(0.000)	
3-month LIBOR	-0.1416***	
	(0.045)	
Regional GDP growth	0.0016	
	(0.012)	
Dummy hidden liabilities	0.3521***	
	(0.108)	
Dummy savings banks	-0.6421***	
	(0.151)	
Dummy private banks	-0.8537***	
	(0.210)	
Constant	-2.2435***	
	(0.280)	
Observations	40,661	
Area under ROC curve	0.859	
Pseudo R^2	0.186	
Cragg-Donald F-stat. Duration Gap Pooled	86.80	
Cragg-Donald F-stat. Duration Gap FE	29.04	
Cragg-Donald F-stat. Swap Use Pooled	26.78	
Cragg-Donald F-stat. Swap Extent Pooled	34.22	
Cragg-Donald F-stat. Swap Extent Time Series	11.08	
Overidentification stat. [p-val.] Duration Gap Pooled	0.057	[0.811]
Overidentification stat. [p-val.] Duration Gap FE	0.073	[0.788]
Overidentification stat. [p-val.] Swap Use Pooled	2.058	[0.151]
Overidentification stat. [p-val.] Swap Extent Pooled	0.875	[0.350]
Overidentification stat. [p-val.] Swap Extent Time Series	0.716	[0.397]

Dependent variable: distress event, including forced closures, restructuring mergers, and capital injections. The model is estimated as a logit regression over the time period from 1994-2011. Coefficients are displayed as marginal effects. All covariates are lagged from the previous year end. Standard errors are clustered at bank level and displayed in parentheses. Significance at the 10%/5%/1% level is marked by */**/***. Cragg-Donald F-statistics for weak identification and overidentification statistics are from the regressions run in Section 4.5 when distress events are included instead of the probability of default and instrumented using hidden liabilities. Overidentification is achieved using two instruments each for either the duration gap or interest rate swap use. Cragg-Donald statistics, on the other hand, are the first stage F-statistics when only the distress events are instrumented and are always carried out as linear probability models using OLS (Angrist, 2001). The critical Stock and Yogo (2005) value for each of these regressions accounting for clustered standard errors is 16.38. The regression for deriving the overidentification statistic with the hedging decision as the dependent variable is a two-step IV-Probit regressions (Newey, 1987) and the overidentification statistic is from Lee (1992). In all other regressions the overidentification test is a Hansen-J test. The overidentification and Cragg-Donald F-statistics in the time-series swap extent regressions are based on the setting proposed by Semykina and Wooldridge (2010).

would have been attributed to funding conditions and experiences of the U.S. savings and loan (S&L) crisis. However, contemporaneous studies confirm the positive relation of short-term interest rates to banks' risk-taking behavior (Jiménez et al., 2012).

We consider *Hidden liabilities* to be exogenous to the risk management decisions examined in Section 4.5. The coefficient is positive as expected and significant with a t-statistic of almost 3.3. Having hidden liabilities on the balance sheet increases the likelihood of default during the following year by 35%, a change of high economic magnitude. Instrumenting actual defaults with the dummy for hidden liabilities in the risk management regressions of Section 4.5 — using defaults as the only variable to be instrumented — we receive weak instrument statistics, which are always above the critical value of 16.38 for the Cragg-Donald F-test adjusted for clustered standard errors. The only exception is the time-series regression of the extent of interest rate swap use, which is analyzed in a panel sample selection setting of Semykina and Wooldridge (2010). In this setting, the F-statistic falls to 11.08, which is, however, still above the old rule of thumb that the F-statistic should exceed 10. As indicated by the t-statistics, *hidden liabilities* are indeed a strong and therefore relevant instrument. In further regressions, where both the actual default and the decision to use swaps or the maturity gap are considered endogenous and therefore instrumented, we can reject tests of overidentifying restrictions conveniently in all cases at the 10% level. Overidentification is achieved using the two instruments for the decision to use interest rate swaps or the maturity gap. As we are, however, interested in the impact the latent variable *Probability of default* has on risk management decisions rather than the actual default, we will not proceed using actual default in the following risk management regressions.

The hazard rate model has both good predictive and discriminatory powers. Statistical power is evaluated using the pseudo R^2, which has a value of 0.189. Discriminatory power is judged using the value of the area under the Receiver Operating Characteristics (ROC) Curve, which is 0.859. Both values are comparatively good considering the parsimonious use of explanatory variables compared with other studies.

Unlike in the U.S., the German banking industry did not undergo a major crisis with its underlying causes in the dynamics of interest rates, like the S&L crisis that affected thrifts in the U.S. during the 1980s. Although we find that defaulting banks were more sensitive to a decrease in the level of interbank rates, we did not include specific variables related to interest rate risk taking, and there thus exists no ex ante mechanical relation between the PDs derived and IRR management.

4.5 Simultaneous Interest Rate Risk Management

Although we estimate the regressions for the (modified) maturity gap and the decision to use interest rate swaps and their extent as a system of simultaneous equations, we will present and discuss the results in different tables. For brevity, we do not display the results of first-stage regressions as these regression tables are similar to the second-stage results for the other risk management decision in the simultaneous equation framework. We estimate the simultaneous equations framework as two-stage least squares (2-SLS) regressions with standard errors generally clustered at the bank level.

The results presented in Table 4.4 show that the coefficients derived from pooled OLS models, controlling with time dummies, are very close to those from Fama-MacBeth regressions, when the swap use dummy is considered exogenous. This holds especially for the total and the non-trading book samples. We therefore argue that pooled models capture cross-sectional variation without too severe a bias. Fama-MacBeth regressions derive the significance of coefficients solely from the time-series variation of coefficients over distinct periods using Newey-West standard errors with automatic lag selection. This approach, however, would treat instruments created in the first stage as variables and not as estimated instruments and standard errors would be underestimated. We will therefore focus on 2-SLS pooled regressions together with between effects IV regressions when we simultaneously investigate interest rate swap use and on-balance-sheet IRR management. Another advantage is that we can then draw on the complete IV statistics available for 2-SLS regressions. Similarly, Table 4.5 compares between effects, Fama-MacBeth and pooled OLS estimators for the extent of interest rate swap use regression models when the modified duration gap is taken as exogenous. Again, pooled OLS gives quite similar results to Fama-MacBeth. The best results are now achieved for the two sub-samples of non-trading and trading book banks.

4.5.1 Maturity Gap

4.5.1.1 Cross-Sectional Variation

Table 4.6 presents the cross-sectional results of the maturity gap equation within the simultaneous risk management framework. As expected, the coefficients of the swap use dummy are significantly positive, indicating that banks deciding to use interest rate swaps are operating with a higher maturity mismatch. On average, commercial banks that use swaps have a 0.16 percentage point higher modified duration gap. The effect is highest for trading book institutions where the effect amounts to 0.65, or 0.48 percentage points, depending on the estimated model, between effects or pooled OLS. The positive coefficients give evidence that, although trading book institutions might use interest rate swaps for the purpose of speculation, they predominantly seem to use them for the purpose of hedg-

Table 4.4: Maturity Gap - Cross-Sectional Models (Exogenous)

	Between effects			Fama-MacBeth			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Dummy interest rate swap use	0.143***	0.104***	0.417***	0.115***	0.0981***	0.373***	0.114***	0.096***	0.247***
	(0.0268)	(0.0271)	(0.1177)	(0.0120)	(0.0138)	(0.00931)	(0.0193)	(0.0199)	(0.0685)
Probability of default (ln)	-0.048***	-0.051***	-0.069***	-0.0127**	-0.0127**	-0.0592***	-0.013**	-0.013**	-0.043**
	(0.0058)	(0.0061)	(0.0200)	(0.00512)	(0.00531)	(0.0109)	(0.0056)	(0.0059)	(0.0173)
Size	0.064***	0.080***	-0.114***	0.0376***	0.0425***	-0.201***	0.040***	0.045***	-0.060*
	(0.0118)	(0.0129)	(0.0337)	(0.00226)	(0.00447)	(0.00795)	(0.0134)	(0.0136)	(0.0354)
Total asset growth	-0.685	-1.295***	1.708	-1.166***	-1.453***	0.923***	-0.988***	-1.317***	0.846**
	(0.4674)	(0.4098)	(1.1546)	(0.241)	(0.277)	(0.259)	(0.1834)	(0.1929)	(0.3915)
Savings deposits	-1.168***	-0.987***	-3.323***	-0.635***	-0.426***	-1.868***	-0.740***	-0.548***	-2.643***
	(0.2175)	(0.2095)	(0.7623)	(0.0723)	(0.0658)	(0.189)	(0.1852)	(0.1799)	(0.6825)
Liquid assets	-0.690***	-0.701***	-0.244	-0.783**	-0.868**	-0.150	-0.473***	-0.481***	-0.154
	(0.1290)	(0.1414)	(0.3543)	(0.260)	(0.296)	(0.116)	(0.0924)	(0.0978)	(0.2396)
Branch HHI	0.005***	0.004**	0.004	0.00748***	0.00641***	0.0159***	0.006***	0.005**	0.012*
	(0.0016)	(0.0018)	(0.0063)	(0.00126)	(0.00145)	(0.00287)	(0.0020)	(0.0020)	(0.0065)
Loan commitments	23.563***	23.173***	17.622**	13.79***	13.57***	16.91***	14.360***	14.116***	8.483*
	(2.4511)	(2.7454)	(7.5005)	(0.853)	(0.867)	(0.483)	(1.8212)	(1.7968)	(4.6977)
Customer loans	0.634***	0.487***	1.907***	0.899***	0.682***	2.761***	1.025***	0.838***	2.369***
	(0.1294)	(0.1114)	(0.4095)	(0.132)	(0.137)	(0.182)	(0.1283)	(0.1262)	(0.3423)
Dummy trading book	-0.159***			-0.0815***			-0.093*		
	(0.0463)			(0.0205)			(0.0487)		
Time dummies	NO	NO	NO	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	19,520	17,322	2,198	19,520	17,322	2,198	19,520	17,322	2,198
Number of banks	2,907	2,624	283	2,907	2,624	283	2,907	2,624	283
R^2	0.423	0.347	0.725	0.385	0.327	0.606	0.398	0.350	0.636

Dependent variable: *modified duration gap*. Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, Fama-MacBeth regressions use Newey-West HAC standard errors with automatic lag selection, and pooled OLS regressions use clustered standard errors at bank level, respectively. Automatic lag length is selected as the integer portion of $12\,(T/100)^{(2/9)}$, where T is the number of periods and equals 12. Significance at the 10%/5%/1% level is marked by */**/***.

Table 4.5: Extent of Interest Rate Swap Use - Cross-Sectional Models (Exogenous)

	Between effects			Fama-MacBeth			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Modified duration gap	0.032	0.110*	-0.211*	0.065	0.184**	-0.165*	0.026	0.143**	-0.185**
	(0.0528)	(0.0654)	(0.1080)	(0.1038)	(0.0809)	(0.0775)	(0.0517)	(0.0644)	(0.0856)
Probability of default (ln)	0.087***	0.035*	0.084*	0.153***	0.098***	0.146***	0.136***	0.080***	0.122***
	(0.0140)	(0.0193)	(0.0434)	(0.0063)	(0.0153)	(0.0218)	(0.0170)	(0.0205)	(0.0332)
Size	0.447***	0.213***	0.497***	0.471***	0.261**	0.465***	0.414***	0.162***	0.467***
	(0.0421)	(0.0770)	(0.0767)	(0.0515)	(0.1109)	(0.0211)	(0.0384)	(0.0585)	(0.0475)
Total asset growth	2.772***	2.812**	1.665	1.101	1.192	0.605	0.630	0.891*	0.378
	(1.0056)	(1.2497)	(2.1721)	(0.6968)	(0.6707)	(0.4330)	(0.4053)	(0.4706)	(0.8338)
Savings deposits	-1.686***	-1.685***	-0.564	-0.920**	-0.621**	-0.857	-1.075**	-0.716	-1.019
	(0.5222)	(0.6434)	(1.6073)	(0.4062)	(0.2673)	(0.7458)	(0.4838)	(0.5357)	(1.0815)
Liquid assets	-0.859***	-0.660*	-1.033	-1.030*	-0.903	-1.116*	-0.629***	-0.383*	-1.033**
	(0.2580)	(0.3431)	(0.6454)	(0.5119)	(0.5083)	(0.5278)	(0.2020)	(0.2058)	(0.4750)
Branch HHI	-0.002	0.001	0.020	0.001	0.006**	-0.003	-0.001	0.005	-0.006
	(0.0054)	(0.0055)	(0.0147)	(0.0018)	(0.0022)	(0.0065)	(0.0054)	(0.0053)	(0.0150)
Past swap experience	2.154***	1.524***	0.268	2.232***	1.699***	0.986***	1.677***	1.009***	0.942**
	(0.2515)	(0.3884)	(1.1297)	(0.3474)	(0.4458)	(0.2817)	(0.2076)	(0.2252)	(0.4758)
Dummy trading book	0.648***			0.525***			0.483***		
	(0.1159)			(0.0506)			(0.1052)		
Inverse Mills ratio	0.946***	0.446*	-1.044	1.022***	0.627*	-0.468**	0.578***	0.083	-0.596*
	(0.1754)	(0.2685)	(0.7208)	(0.2656)	(0.3422)	(0.2027)	(0.1563)	(0.1716)	(0.3185)
Time dummies	NO	NO	NO	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Observations	7,399	5,725	1,674	7,399	5,725	1,674	7,399	5,725	1,674
Number of banks	1,509	1,257	252	1,509	1,257	252	1,509	1,257	252
R^2	0.272	0.079	0.487	0.268	0.090	0.452	0.269	0.115	0.428

Dependent variable: *extent of interest rate swap use*. Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, Fama-MacBeth regressions use Newey-West HAC standard errors with automatic lag selection, and pooled OLS regressions use clustered standard errors at bank level, respectively. Automatic lag length is selected as the integer portion of $12\,(T/100)^{((2/9))}$, where T is the number of periods and equals 12. Significance at the 10%/5%/1% level is marked by */**/***.

ing. This confirms previous results from Memmel and Schertler (2011) who demonstrate, based on the effect of interest rate swap usage on the variability of net interest income, that interest rate swaps are mainly used for hedging purposes.

The effect of the PD supports the predictions of theoretical risk management models, such as Froot et al. (1993) and Froot and Stein (1998), that the potential distress cost leads commercial banks to take less IRR. Again, this effect is most pronounced for trading book institutions. As trading book institutions receive more of their funding from capital markets and arms-length relationships in interbank markets, whereas the majority of pure banking book institutions receive interbank loans from their associated head institutions (Ehrmann and Worms, 2004), these results can be interpreted as the effect of risk taking on the cost of external finance, as also found by Brewer et al. (1996).

Size leads pure banking book institutions to take more, but trading book institutions to take less IRR on the balance sheet. Business opportunities show the expected negative effect as predicted by Froot et al. (1993) and Froot and Stein (1998) only for pure banking book institutions. For trading book financial intermediaries the opposite holds, although the coefficients are only significant in the pooled OLS setting. Asset and funding liquidity both lead banks to engage in less maturity transformation. This finding is not surprising for liquid assets as a substantial portion of these assets have short-term maturity that reduces the modified duration gap. For savings deposits the finding is, however, surprising as the short-term funding nature of deposits leads to a higher duration gap per se. On the other hand, many small regional banks with strong deposit funding lack business opportunities and hold proportionally large liquidity buffers, often deposited via interbank loans at their head institutions. The results of all coefficients presented so far are consistent with those found by Purnanandam (2007) in cross-sectional regressions where Fama-MacBeth estimators have been applied. More concentrated and therefore less competitive markets lead to more on-balance-sheet interest rate risk taking — giving support of the theory developed by Boyd and De Nicoló (2005).

The coefficients for Customer loans and Loan commitments are positive and significant at the 1% level in all regressions. Banks with a higher share of customer loan volume indeed have a higher duration gap as already documented by Ehrmann and Worms (2004). The positive coefficient for the ratio of loan commitments confirms the results of Berger et al. (2005) that banks use loan commitments to gather information on borrower quality and finally to offer loans with longer maturity. The significance levels serve as upfront indicators of instrument relevance in the swap use regressions presented in Section 4.5.2.

The first-stage instrumentation process of *Interest rate swap use* — which has been carried out for simplicity as a linear probability model — proves instrument relevance as the test statistics for weak instruments are always conveniently above the critical value of 19.93.[33] The magnitude of the weak identification tests is largely driven by the variable Past swap experience. Overidentification tests strengthen our arguments as to the exogeneity of the instruments included. Interestingly, the Durbin-Wu-Hausman test statistics indicate that the choice of using interest rate swaps is exogenous to the magnitude of the maturity gap. Hence, instrumenting the dummy variable of interest rate swap use is not necessary.

[33] Using fitted values from a first-stage probit model as instruments — as described in Wooldridge (2010) — does not change the results qualitatively. This also holds for the fixed effects time-series models. However, this approach would not allow a test for overidentification.

Table 4.6: Maturity Gap - Simultaneous Cross-Sectional Models

	Between effects			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Dummy interest rate swap use	0.157***	0.119**	0.646***	0.154***	0.131***	0.484***
	(0.0491)	(0.0534)	(0.2166)	(0.0481)	(0.0501)	(0.1574)
Probability of default (ln)	-0.049***	-0.051***	-0.088***	-0.014**	-0.013**	-0.054***
	(0.0061)	(0.0057)	(0.0199)	(0.0056)	(0.0059)	(0.0183)
Size	0.061***	0.077***	-0.245***	0.033**	0.038**	-0.221***
	(0.0133)	(0.0150)	(0.0286)	(0.0158)	(0.0162)	(0.0279)
Total asset growth	-0.678	-1.286***	1.724	-0.974***	-1.305***	1.064**
	(0.4301)	(0.4134)	(1.0803)	(0.1835)	(0.1932)	(0.4134)
Savings deposits	-1.163***	-0.982***	-2.826***	-0.731***	-0.540***	-1.944***
	(0.2408)	(0.2087)	(0.7623)	(0.1846)	(0.1790)	(0.6956)
Liquid assets	-0.687***	-0.699***	-0.326	-0.469***	-0.479***	-0.100
	(0.1359)	(0.1496)	(0.4197)	(0.0923)	(0.0977)	(0.2475)
Branch HHI	0.005**	0.004**	0.005	0.006***	0.005**	0.014**
	(0.0020)	(0.0021)	(0.0071)	(0.0020)	(0.0020)	(0.0065)
Loan commitments	23.516***	23.117***	26.046***	14.252***	14.007***	15.998***
	(2.7681)	(2.4296)	(7.6293)	(1.8286)	(1.8048)	(5.0454)
Customer loans	0.637***	0.490***	2.107***	1.028***	0.839***	2.713***
	(0.1170)	(0.1425)	(0.3539)	(0.1283)	(0.1262)	(0.3428)
Dummy trading book	-0.160***			-0.097**		
	(0.0561)			(0.0489)		
Time dummies	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES
Observations	19,520	17,322	2,198	19,520	17,322	2,198
Number of banks	2,907	2,624	283	2,907	2,624	283
Adj. GR^2	0.417	0.342	0.672	0.395	0.348	0.584
Cragg-Donald F-stat.				651.8	574.3	166.9
Overidentification stat.				0.291	0.308	2.452
p-val				0.590	0.579	0.117
Endogeneity stat.				0.975	0.551	1.096
p-val				0.323	0.458	0.295

Dependent variable: *modified duration gap*. All regressions are 2SLS regressions with *dummy interest rate swap use* being instrumented with the *average board experience* and a *past swap use dummy* in a linear probability model (see, Angrist, 2001). Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, and pooled OLS regressions use clustered standard errors at bank level, respectively. Standard errors are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by */**/***. Cragg-Donald F-stat. is the F-statistic for weak instruments. The critical value of the Cragg-Donald F-statistic taking clustered standard errors into account is 19.93. Overidentification stat. is the test statistic of the Hansen-J test on instrument validity. Endogeneity stat. is the χ^2-statistic of the Durbin-Wu-Hausman test on the endogeneity of the *dummy interest rate swap use*. Adj. GR^2 is the adjusted generalized R^2 of Pesaran and Smith (1994).

4.5.1.2 Time-Series Variation

In this Section, we investigate the time-series behavior of the modified duration gap and present the results in Table 4.7. The use of panel data allows us to include macroeconomic variables which we can use to prove market timing behavior in on-balance-sheet IRR exposure. Our standard model (Panel A) includes time dummies to control for the potential impact of several macroeconomic indicators. Compared to the cross-sectional model, the time-series model has significantly lower explanatory power based on the coefficient of determination R^2. The variables included are therefore better able to distinguish cross-sectional differences between banks than to explain the adjustment of the duration gap over time.

In the baseline model, we find the coefficients for the *Interest rate swap use* to be not significant except for the sub-group of banks that changed their status of swap use at least once, which we refer to as "starters". Most of these banks started hedging during the sample period and therefore changed from non-users to users at least once. For this sub-sample we find a coefficient of 0.15 percentage points, significant at the 1% level and comparable in magnitude to the cross-sectional models. As the majority of banks, around two-thirds, not change their swap use status once during the sample period, and either never uses swaps or does so in all years, too little intertemporal variation exists for the fixed effects estimator to deliver significant results in the other three samples.

For the other explanatory variables, we find the same coefficient sign in the time-series models as in the cross-sectional models. The only exemption is *Size*, which now has significantly negative coefficients. Hence, as banks become larger, they decrease their on-balance-sheet exposure resulting from term transformation. One explanation is that bigger banks start engaging in other business lines that generate fee and trading income. The significance of loan commitments decreases in the trading book sample, but is still significant at the 10% level. The effect of competition shows ambiguous results. Whereas decreasing competition leads non-trading book institutions to take on less risk, the opposite holds for trading book banks. However, mixed empirical findings for the relation between competition and risk taking have already been documented by Boyd and De Nicoló (2005).

The macroeconomic variables confirm results from previous analysis. Banks increase their duration gap when the yield curve becomes steeper and maturity transformation becomes more profitable. Similar results were found by Purnanandam (2007) and Memmel and Schertler (2011). As the level of the short-term 1-year government yield is highly collinear to the slope of the yield curve, we do not include it as an extra variable but create an interaction term with the slope instead. These interaction terms are significantly negative and confirm theories related to the risk-taking channel of monetary policy (Borio and Zhu, 2012). Jiménez et al. (2012) find that short-term rates matter for banks' risk taking, whereas the long-term 10-year rate has no significant impact. During times of high short-term rates, when short-term lending funded with deposits that pay less than market rates is also profitable, banks engage in less maturity transformation (Panel B). Interestingly, banks decrease their duration gap in times of uncertainty in interbank markets, measured by a higher spread of the 1-year LIBOR over the 1-year government rate (Panel C and D). However, when interbank uncertainty arises contemporaneously with a steep yield curve, banks decrease their maturity mismatch less drastically, as there are still profits to earn from maturity transformation (Panel D).

4.5.2 Interest Rate Swap Use Decision

In this section we analyze the determinants for the use of interest rate swaps by applying pooled probit models into which we include macroeconomic variables. The results are presented in Table 4.8. Again, the baseline model in Panel A includes time dummies, whereas the other model specifications use the same sets of macroeconomic variables as in the time-series setting of the duration gap analysis.

Maturity gap has the expected positive coefficients, always significant at the 1% level. Pure banking book institutions show a three to four times higher sensitivity to on-balance-sheet IRR than banking book institutions. Once the smaller non-trading book banks decide to use interest rate swaps, they can hedge the IRR from maturity transformation and can accept short-term deposits and make long-term loans, as long as they keep their overall exposure below the "outlier" thresholds of the IRR regulation schemes.

The sign of the coefficient of the PD provides evidence on the predictions of static hedging models (Froot et al., 1993; Froot and Stein, 1998). The higher the default risk and the associated cost of bankruptcy, the higher the propensity to use interest rate swaps. Again, the sensitivity of trading book financial intermediaries, which are more likely to depend on their credit rating in interbank and capital markets, is higher in magnitude. However, these banks might use interest rate swaps, at least partly, for speculation purposes too. Also for banks, we find the empirically well-documented effect that larger entities are more

Table 4.7: Maturity Gap - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel A				*Panel B*	
Dummy interest rate swap use	0.001	-0.014	0.199	0.156***	0.050	0.034	0.247	0.094*
	(0.0466)	(0.0481)	(0.1617)	(0.0493)	(0.0467)	(0.0483)	(0.1634)	(0.0487)
Probability of default (ln)	-0.015***	-0.013**	-0.017	-0.055***	-0.051***	-0.054***	-0.032**	-0.050***
	(0.0056)	(0.0060)	(0.0152)	(0.0076)	(0.0049)	(0.0052)	(0.0143)	(0.0080)
Size	-0.464***	-0.513***	-0.215*	-0.180*	-0.303***	-0.348***	-0.105	-0.482***
	(0.0758)	(0.0847)	(0.1245)	(0.0952)	(0.0631)	(0.0713)	(0.1003)	(0.1066)
Total asset growth	-0.227**	-0.377***	0.659***	-0.613***	-0.527***	-0.662***	0.454*	-0.582***
	(0.0994)	(0.1069)	(0.2473)	(0.1549)	(0.0940)	(0.1016)	(0.2358)	(0.1632)
Savings deposits	-0.416***	-0.374***	-0.903**	-1.029***	-0.734***	-0.671***	-1.169***	-0.978***
	(0.1317)	(0.1377)	(0.3775)	(0.2010)	(0.1292)	(0.1350)	(0.3609)	(0.1943)
Liquid assets	-0.407***	-0.387***	-0.337***	-0.382***	-0.499***	-0.517***	-0.327**	-0.367***
	(0.0543)	(0.0597)	(0.1278)	(0.0740)	(0.0555)	(0.0613)	(0.1285)	(0.0749)
Branch HHI	0.004	0.001	0.021***	0.005	-0.005**	-0.009***	0.015**	-0.001
	(0.0030)	(0.0031)	(0.0070)	(0.0045)	(0.0026)	(0.0027)	(0.0060)	(0.0038)
Loan commitments	4.758***	5.117***	3.091*	5.850***	5.805***	6.409***	3.279*	6.275***
	(1.0073)	(1.1317)	(1.8366)	(1.7551)	(0.9971)	(1.1324)	(1.8198)	(1.6707)
Customer loans	1.793***	1.700***	2.744***	1.438***	1.461***	1.319***	2.700***	1.551***
	(0.1395)	(0.1443)	(0.3955)	(0.2456)	(0.1396)	(0.1426)	(0.4098)	(0.2387)
Dummy trading book	-0.006			0.022	0.042			0.070
	(0.0532)			(0.0669)	(0.0531)			(0.0636)
Yield curve slope					0.079***	0.078***	0.087***	0.071***
					(0.0061)	(0.0065)	(0.0177)	(0.0096)
Yield curve slope x 1-year interest rate					-0.038***	-0.038***	-0.045***	-0.041***
					(0.0048)	(0.0051)	(0.0130)	(0.0080)
Adj. GR^2	0.248	0.264	0.231	0.213	0.157	0.157	0.210	0.164
Kleibergen-Paap F-stat.	342.5	309.0	34.71	251.8	357.6	321.9	37.37	260.6
Overidentification stat.	0.021	0.098	0.696	0.715	1.500	2.076	0.735	0.441
p-val	0.886	0.755	0.404	0.398	0.221	0.150	0.391	0.507
Endogeneity stat.	0.204	0.385	0.693	6.349	0.347	0.163	1.090	1.928
p-val	0.652	0.535	0.405	0.012	0.556	0.687	0.297	0.165

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Table 4.7 continued: Maturity Gap - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
	Panel C				*Panel D*			
Dummy interest rate swap use	0.102**	0.093*	0.265	0.159***	0.100**	0.089*	0.257	0.160***
	(0.0475)	(0.0493)	(0.1670)	(0.0501)	(0.0474)	(0.0492)	(0.1682)	(0.0497)
Probability of default (ln)	-0.069***	-0.072***	-0.042***	-0.070***	-0.071***	-0.073***	-0.049***	-0.072***
	(0.0046)	(0.0049)	(0.0133)	(0.0073)	(0.0045)	(0.0048)	(0.0131)	(0.0071)
Size	-0.146**	-0.156**	-0.084	-0.300***	-0.158**	-0.183**	-0.060	-0.311***
	(0.0644)	(0.0739)	(0.1029)	(0.1076)	(0.0637)	(0.0730)	(0.1013)	(0.1060)
Total asset growth	-0.637***	-0.761***	0.390	-0.638***	-0.557***	-0.673***	0.394*	-0.565***
	(0.0926)	(0.0999)	(0.2384)	(0.1567)	(0.0935)	(0.1013)	(0.2381)	(0.1595)
Savings deposits	-0.917***	-0.849***	-1.341***	-1.114***	-0.805***	-0.728***	-1.349***	-1.019***
	(0.1319)	(0.1381)	(0.3568)	(0.2009)	(0.1334)	(0.1389)	(0.3693)	(0.2056)
Liquid assets	-0.526***	-0.534***	-0.342***	-0.410***	-0.579***	-0.596***	-0.370***	-0.448***
	(0.0527)	(0.0578)	(0.1285)	(0.0706)	(0.0547)	(0.0603)	(0.1294)	(0.0729)
Branch HHI	-0.008***	-0.011***	0.012*	-0.004	-0.010***	-0.013***	0.010*	-0.005
	(0.0025)	(0.0027)	(0.0059)	(0.0038)	(0.0025)	(0.0027)	(0.0060)	(0.0038)
Loan commitments	6.383***	7.090***	3.546*	6.633***	5.992***	6.595***	3.585**	6.189***
	(1.0201)	(1.1613)	(1.8101)	(1.7259)	(1.0294)	(1.1732)	(1.8172)	(1.7378)
Customer loans	1.276***	1.104***	2.674***	1.311***	1.290***	1.127***	2.685***	1.321***
	(0.1439)	(0.1456)	(0.4239)	(0.2527)	(0.1441)	(0.1457)	(0.4297)	(0.2538)
Dummy trading book	0.024			0.049	0.022			0.048
	(0.0543)			(0.0687)	(0.0555)			(0.0696)
Yield curve slope					0.049***	0.049***	0.051***	0.041***
					(0.0046)	(0.0049)	(0.0142)	(0.0068)
EURIBOR spread	-0.085***	-0.090***	-0.040	-0.102***	-0.038***	-0.049***	0.060*	-0.063***
	(0.0113)	(0.0119)	(0.0333)	(0.0175)	(0.0119)	(0.0127)	(0.0312)	(0.0186)
Yield curve slope x EURIBOR spread	0.048***	0.041***	0.096***	0.041***				
	(0.0075)	(0.0081)	(0.0229)	(0.0115)				
Adj. GR^2	0.145	0.145	0.204	0.154	0.150	0.151	0.199	0.156
Kleibergen-Paap F-stat.	351.6	316.1	38.79	251.2	355.1	320.0	37.96	256.8
Overidentification stat.	1.773	2.279	1.023	0.888	1.879	2.430	0.879	0.937
p-val	0.183	0.131	0.312	0.346	0.170	0.119	0.348	0.333
Endogeneity stat.	2.551	2.391	1.261	6.341	2.132	1.894	1.079	6.126
p-val	0.110	0.122	0.261	0.012	0.144	0.169	0.299	0.013
Observations	18,916	16,772	2,144	7,969	18,916	16,772	2,144	7,969
Number of banks	2,429	2,175	254	862	2,429	2,175	254	862

Dependent variable: *extent of interest rate swap use*. All regressions are 2SLS regressions according to the sample selection correction of Semykina and Wooldridge (2010) with *modified duration gap* being instrumented with the *customer loans* and *loan commitments*. Standard errors in parentheses are clustered at bank level and are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by */**/***. Cragg-Donald F-stat. is the F-statistic for weak instruments with a critical value of 19.93 taking clustered standard errors into account. Endogeneity stat. is the χ^2-statistic of the Durbin-Wu-Hausman test on the endogeneity of Modified duration gap. Adj. GR^2 is the adjusted generalized (within) R^2 of Pesaran and Smith (1994).

likely to use OBS derivatives. This is most likely due to economies of scale in establishing risk management departments that are proficient enough to use interest rate swaps.

So far, all our results are consistent with those of Purnanandam (2007). The major difference is the coefficients related to bank liquidity measures, for which Purnanandam finds significantly negative relationships. We find that savings deposits have no impact on the interest rate swap use decision. The buffer stock of liquid assets is found to be insignificant for trading book institutions, but significantly negative for pure banking book intermediaries. This indicates that these banks consider liquid assets to be a complementary hedging tool, whereas risk management theory stresses the substitutionary relation (e.g., Bolton et al., 2013). One potential explanation for this finding lies in the role that liquidity buffers have in the theory of intertemporal smoothing of non-diversifiable liquidity and interest rate risk (Allen and Gale, 1997).

Competition is not found to have an effect on banks' likelihood to use swaps, although theory would have suggested so (Adam et al., 2007). Zhu (2011) finds significant effects from hedging on competition and vice versa. However, she investigates unregulated industries' commodity price hedging. In the regulated banking industry, competition has no effect on the decision to use swaps after controlling for all the other determinants that affect interest rate risk taking.

Past swap experience has the expected positive sign and coefficients are far above 1 and have a significance level of 1% in all samples and regression setups. Average board experience, on the other hand, reduces the likelihood of the use of interest rate swaps and is always conveniently significant at 5%. The negative effects are most pronounced for trading book institutions. These results contradict those found in the literature hitherto. Zhu (2012) finds that younger and therefore less experienced CEOs are less likely to use OBS hedging.

The macroeconomic variables serve as indicators of market timing in hedging decisions. Pure banking book institutions are less likely to use swaps when the yield curve is steep (Panel B). These findings are consistent with Memmel and Schertler (2011). As non-trading book banks can use interest rate swaps only for hedging purposes, they hedge less of their floating-rate debt exposure in times when corporates also hedge less (Faulkender, 2005; Vickery, 2008). For trading book banks, we find insignificant or significantly positive relationships. Here, it has to be taken into account that these banks can use interest rate swaps for speculation on the yield curve and positive coefficients can indicate increasing off-balance-sheet IRR exposure. The interaction term with the 1-year yield is significantly negative for all samples (Panel B).[34] Interbank funding uncertainty increases banks' likelihood of using interest rate swaps (Panel C and D). Interestingly, both the overall and aggregate sectoral quotas of banks that use interest rate swaps are highly correlated with the LIBOR spread. Sectoral quotas have been calculated by separating savings, cooperative and private commercial banks. Hence, funding uncertainty seems to be a major driver of the swap use decision on an industry level. This is further evidence for the dynamic risk management theories that incorporate liquidity issues into hedging decisions. Furthermore, our finding is supported by the increasing use of overnight index

[34] It should be noted that the elasticities of interacted variables in probit models should be interpreted with caution as the correction proposed by Ai and Norton (2003) has not been applied. However, we derive similar coefficients in magnitude for the interacted and all other variables from linear probability models (LPM).

swaps in the banking industry. Banks seem especially interested in hedging against a potential increase in short-term wholesale funding exposure and not so much the IRR that results from transforming savings deposits into long-term loans. Again, when uncertainty is accompanied by a steep yield curve making term transformation profitable, the effect of the LIBOR spread becomes smaller (Panel D).

Customer loans and loan commitments are relevant instruments that conveniently pass the weak instrument tests and always have Cragg-Donald F-statistics above the threshold of 19.93. Their validity is supported using overidentification tests that are insignificant for all samples being estimated. The exogeneity tests of Smith and Blundell (1986) indicate that, for pure banking book institutions, the maturity gap is an endogenous driver of their decision to hold swaps, but exogeneity cannot be rejected for trading book banks as well as starters.

4.5.3 Extent of Interest Rate Swap Use

4.5.3.1 Cross-Sectional Variation

Table 4.9 shows the cross-sectional results of the extent of interest rate swaps used for between effects and a pooled specification. For trading book banks, only three variables are found to be significant. The significant determinants are the PD, which increases the extent of interest rate swap use, Size, which also has a significantly positive impact, and the Past swap experience. Although only three variables are significant, the R-squares are higher for trading book bank samples than for pure banking book institution samples. As

Table 4.8: Interest Rate Swap Use Decision - Simultaneous Pooled Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel A				*Panel B*	
Modified duration gap	0.615***	0.852***	0.241**	0.420***	0.624***	0.909***	0.217**	0.384***
	(0.0867)	(0.1305)	(0.1029)	(0.0874)	(0.0875)	(0.1420)	(0.0984)	(0.0929)
Probability of default (ln)	0.041***	0.032***	0.095***	0.027***	0.046***	0.043***	0.091***	0.024***
	(0.0074)	(0.0075)	(0.0228)	(0.0081)	(0.0076)	(0.0077)	(0.0221)	(0.0080)
Size	0.450***	0.445***	0.254***	0.177***	0.446***	0.434***	0.251***	0.181***
	(0.0169)	(0.0189)	(0.0516)	(0.0186)	(0.0195)	(0.0201)	(0.0514)	(0.0205)
Total asset growth	0.111	0.609	0.394	0.054	0.350	0.921**	0.252	0.421
	(0.3040)	(0.3994)	(0.8718)	(0.3856)	(0.3089)	(0.4482)	(0.8504)	(0.3409)
Savings deposits	-0.140	-0.089	0.209	0.202	-0.002	0.095	0.280	0.255
	(0.2283)	(0.2136)	(0.6239)	(0.2636)	(0.2245)	(0.2375)	(0.6162)	(0.2352)
Liquid assets	0.340***	0.531***	-0.193	0.174	0.346***	0.596***	-0.286	0.116
	(0.1145)	(0.1477)	(0.2865)	(0.1109)	(0.1244)	(0.1554)	(0.3122)	(0.1241)
Branch HHI	0.001	0.003	-0.005	-0.001	0.001	0.003	-0.005	-0.001
	(0.0021)	(0.0023)	(0.0066)	(0.0030)	(0.0020)	(0.0024)	(0.0078)	(0.0028)
Past swap experience	1.700***	1.688***	1.919***	1.070***	1.697***	1.679***	1.924***	1.091***
	(0.0299)	(0.0341)	(0.1129)	(0.0437)	(0.0340)	(0.0377)	(0.1218)	(0.0385)
Avg. board experience	-0.010***	-0.009***	-0.027**	-0.012***	-0.010***	-0.009***	-0.025**	-0.011***
	(0.0025)	(0.0027)	(0.0116)	(0.0032)	(0.0027)	(0.0028)	(0.0104)	(0.0031)
Dummy trading book	0.285***				0.282***			
	(0.0506)				(0.0499)			
Yield curve slope					-0.072***	-0.115***	0.113*	-0.012
					(0.0204)	(0.0217)	(0.0613)	(0.0238)
Yield curve slope x 1-year interest rate					-0.051***	-0.028**	-0.131***	-0.114***
					(0.0121)	(0.0137)	(0.0358)	(0.0148)
Time dummies	YES	YES	YES	YES	NO	NO	NO	NO
Adj. CR^2	0.443	0.401	0.339	0.166	0.443	0.400	0.340	0.162
Kleibergen-Paap F-stat.	47.377	33.235	55.653	33.295	42.116	27.695	55.329	32.607
Overidentification stat.	2.342	1.780	0.0807	2.471	1.435	0.723	0.118	1.664
p-val.	0.126	0.182	0.776	0.116	0.231	0.395	0.731	0.197
Endogeneity stat.	19.46	30.30	1.515	8.489	19.47	31.21	2.271	6.760
p-val.	0.000	0.000	0.218	0.004	0.000	0.000	0.132	0.009

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Table 4.8 continued: Interest Rate Swap Use Decision - Simultaneous Pooled Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel C				*Panel D*	
Modified duration gap	0.593***	0.900***	0.216***	0.326***	0.613***	0.937***	0.210**	0.341***
	(0.1108)	(0.1409)	(0.0823)	(0.1111)	(0.1137)	(0.1603)	(0.0895)	(0.1094)
Probability of default (ln)	0.042***	0.043***	0.080***	0.010	0.041***	0.044***	0.075***	0.009
	(0.0070)	(0.0090)	(0.0208)	(0.0090)	(0.0073)	(0.0079)	(0.0193)	(0.0076)
Size	0.446***	0.431***	0.252***	0.181***	0.447***	0.431***	0.250***	0.182***
	(0.0175)	(0.0176)	(0.0421)	(0.0179)	(0.0171)	(0.0205)	(0.0488)	(0.0196)
Total asset growth	0.282	0.848**	0.266	0.156	0.151	0.732**	0.106	0.023
	(0.3191)	(0.3895)	(0.8963)	(0.3820)	(0.3182)	(0.3453)	(0.9581)	(0.3449)
Savings deposits	0.035	0.207	0.126	0.152	-0.096	0.077	-0.043	-0.035
	(0.2242)	(0.2503)	(0.6025)	(0.2387)	(0.2097)	(0.2215)	(0.6077)	(0.2829)
Liquid assets	0.223	0.493***	-0.292	-0.068	0.307**	0.611***	-0.294	0.012
	(0.1386)	(0.1488)	(0.2518)	(0.1222)	(0.1420)	(0.1928)	(0.2540)	(0.1117)
Branch HHI	0.000	0.002	-0.007	-0.002	0.001	0.003	-0.008	-0.002
	(0.0020)	(0.0023)	(0.0063)	(0.0027)	(0.0023)	(0.0022)	(0.0070)	(0.0028)
Past swap experience	1.693***	1.670***	1.920***	1.084***	1.694***	1.670***	1.923***	1.090***
	(0.0304)	(0.0346)	(0.1232)	(0.0394)	(0.0305)	(0.0314)	(0.1115)	(0.0396)
Avg. board experience	-0.010***	-0.009***	-0.027**	-0.011***	-0.010***	-0.009***	-0.026**	-0.011***
	(0.0029)	(0.0027)	(0.0114)	(0.0032)	(0.0024)	(0.0030)	(0.0112)	(0.0033)
Yield curve slope					-0.112***	-0.143***	0.001	-0.098***
					(0.0201)	(0.0204)	(0.0500)	(0.0228)
EURIBOR spread	0.250***	0.266***	0.238*	0.343***	0.185***	0.161***	0.380***	0.331***
	(0.0411)	(0.0471)	(0.1388)	(0.0612)	(0.0296)	(0.0310)	(0.0946)	(0.0430)
Yield curve slope x EURIBOR spread	-0.078***	-0.116***	0.106	-0.032				
	(0.0253)	(0.0276)	(0.0766)	(0.0321)				
Time dummies	NO	NO	NO	NO	NO	NO	NO	NO
Adj. CR^2	0.441	0.399	0.339	0.157	0.442	0.399	0.339	0.159
Kleibergen-Paap F-stat.	36.749	22.640	55.387	28.516	35.917	22.033	54.664	28.067
Overidentification stat.	0.970	0.403	0.121	1.110	1.159	0.531	0.112	1.300
p-val.	0.325	0.526	0.728	0.292	0.282	0.466	0.738	0.254
Endogeneity stat.	14.16	24.38	2.247	2.881	14.92	25.81	2.542	3.212
p-val.	0.000	0.000	0.134	0.090	0.000	0.000	0.111	0.073
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES
Observations	19,336	17,166	2,170	7,980	19,336	17,166	2,170	7,980

Dependent variable: *dummy interest rate swap use*. Coefficients display marginal effects. All regressions are two-step IV-Probit regressions (Newey, 1987) with *modified duration gap* being instrumented with *customer loans* and *loan commitments*. Kleibergen-Paap F-stat. is the weak instruments statistic. The overidentification test displays the test statistic of Lee (1992). The endogeneity test the χ^2 Wald statistic of Smith and Blundell (1986). Standard errors in parentheses are bootstrapped with 100 repetitions. Significance at the 10%/5%/1% level is marked by */**/***. Adj. CR^2 is the generalized R^2 Taylor (1997) proposes for censored and limited dependent data.

the cross-sectional estimators should explain constant extent of swap use, whereas we cannot distinguish whether interest rate swaps are used for speculation or hedging purposes, the assumptions underlying the estimators may be violated. The results should therefore be interpreted with caution. In particular, concluding that the positive coefficient found for the Probability of default indicates a reduction of IRR through interest rate swaps is not straightforward. The opposite could be true, namely that trading book banks with a higher likelihood of default increase their risk by speculating on interest rate movements, as predicted by dynamic risk management models for financially constrained firms (e.g., Bolton et al., 2013).

For the sample of pure banking book institutions, we find results in line with those Purnanandam (2007) obtained when he investigated interest derivatives for hedging purposes. Banks with higher duration gaps hold significantly more interest rate swaps, and banks with a higher cost of distress also increase their swap use to hedge IRR, consistent with the implications for the risk management behavior of unconstrained firms in corporate finance theory. As for trading book banks, Size also shows significantly positive coefficients and asset growth is found to be insignificant.

Liquidity endowments, in general, reduce the volume of swaps held. This is consistent with the predictions of modern dynamic risk management theory, where cash is considered a substitute for hedging activities (e.g., Bolton et al., 2013). Savings deposits as an indicator of stable funding sources significantly reduce the extent of interest rate swaps. The same holds for the buffer of liquid assets, however only when a between estimator is used. Competition has no influence on the extent of interest rate swaps.

Controlling for sample selection bias is only necessary for the pure banking book sample as well as the total sample, but not for the trading book sample. The reduction of sample size conditional on using swaps is most substantial for non-trading book institutions, while the observations in the trading book sample drop only slightly. Observations decrease by more than two-thirds in the pure banking book sample from 17,166 to 5,725, whereas the reduction is only around 20% for the banking book institutions, from 2,170 to 1,701.

Again, the instruments pass the weak instrument tests and are clearly above the threshold of 19.93 calculated by Stock and Yogo (2005). Instrument validity is confirmed by the Hansen-J test of overidentification. The Durbin-Wu-Hausman exogeneity tests indicate that the modified duration gap is indeed an endogenous determinant of the nominal volume of banks' interest rate swaps. This result holds for all sub-samples of the pooled OLS models.

4.5.3.2 Time-Series Variation

In a time-series setting — results are presented in Table 4.10 — the duration gap has a positive and even larger impact on the extent of interest rate swaps used than in the cross-sectional settings. To address problems of unobserved heterogeneity and endogeneity as well as sample selection, we estimate these models following Semykina and Wooldridge (2010). The impact is largest for commercial banks that start using interest rate swaps during the sample period. In contrast to the cross-sectional regressions, we do not find a significant influence of the probability of default in any of the regressions run on the swap extent. The same is true of liquid asset endowments and mostly also of savings

Table 4.9: Extent of Interest Rate Swap Use - Simultaneous Cross-Sectional Models

	Between effects			Pooled OLS		
	Total sample	Non-trading book	Trading book	Total sample	Non-trading book	Trading book
Modified duration gap	0.612***	0.429**	0.274	0.819***	1.044***	0.160
	(0.1673)	(0.2176)	(0.2437)	(0.1951)	(0.2552)	(0.1608)
Probability of default (ln)	0.066***	0.043**	0.060	0.123***	0.109***	0.074**
	(0.0178)	(0.0188)	(0.0504)	(0.0188)	(0.0212)	(0.0349)
Size	0.633***	0.458***	0.685***	0.821***	0.775***	0.602***
	(0.0899)	(0.0972)	(0.1015)	(0.0992)	(0.1265)	(0.0744)
Total asset growth	1.481	2.448**	-0.570	-0.075	0.904	-0.874
	(1.0879)	(1.0751)	(2.2389)	(0.5186)	(0.6386)	(0.8354)
Savings deposits	-1.534**	-1.982***	-0.170	-0.706	-1.252**	-0.656
	(0.6022)	(0.5605)	(1.9363)	(0.6101)	(0.5857)	(1.2594)
Liquid assets	-0.654**	-0.797**	-0.508	-0.203	0.003	-0.655
	(0.2831)	(0.3862)	(0.7662)	(0.2346)	(0.2714)	(0.4109)
Branch HHI	0.007	0.006	0.021	0.009*	0.015**	-0.004
	(0.0049)	(0.0048)	(0.0185)	(0.0055)	(0.0057)	(0.0156)
Past swap experience	3.532***	2.939***	1.136*	4.236***	4.153***	1.440***
	(0.4198)	(0.4208)	(0.6264)	(0.4682)	(0.5395)	(0.3190)
Dummy trading book	0.698***			0.628***		
	(0.1160)			(0.1127)		
Inverse Mills ratio	2.074***	1.544***		2.661***	2.631***	
	(0.3281)	(0.3193)		(0.3737)	(0.4307)	
Time dummies	NO	NO	NO	YES	YES	YES
Banking group dummies	YES	YES	YES	YES	YES	YES
Observations	7,399	5,725	1,701	7,399	5,725	1,701
Number of banks	1,509	1,257	255	1,509	1,257	255
Adj. GR^2	0.318	0.0997	0.499	0.312	0.133	0.446
Cragg-Donald F-stat.				37.60	21.56	53.65
Overidentification stat.				0.338	0.150	0.350
p-val.				0.561	0.699	0.554
Endogeneity stat.				15.67	10.97	5.305
p-val.				0.000	0.000	0.021

Dependent variable: *extent of interest rate swap use*. All regressions are 2SLS regressions with *modified duration gap* being instrumented with the *customer loans* and *loan commitments*. Standard errors in parentheses. Between effects regressions use bootstrapped standard errors with 100 repetitions, and pooled OLS regressions use clustered standard errors at bank level, respectively. Standard errors are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by */**/***. Sample selection correction is achieved according to Wooldridge (2010). Cragg-Donald F-stat. is the F-statistic for weak instruments. The critical value of the Cragg-Donald F-statistic taking clustered standard errors into account is 19.93. Overidentification stat. is the test statistic of the Hansen-J test on instrument validity. Endogeneity stat. is the χ^2-statistic of the Durbin-Wu-Hausman test on the endogeneity of *modified duration gap*. Adj. GR^2 is the adjusted generalized R^2 of Pesaran and Smith (1994).

deposits. These results are in contrast to our cross-sectional findings and also to the time-series models of Purnanandam (2007), who finds a significantly negative impact for both variables.

Size has a significantly positive impact on the extent of interest rate swap use and is larger than in the cross-sectional regressions. Total asset growth is largely found to be insignificant, except for trading book institutions, where significantly negative coefficients can be observed. However, again this finding is hard to interpret as we do not know whether swaps are held for speculative or for hedging purposes.

The exogeneity tests cannot reject the endogeneity of the duration gap, as in the cross-sectional regressions. The critical threshold of 19.93, as stated by Stock and Yogo (2005), for the Cragg-Donald F-tests is not passed in all regression models. However, even the smallest values observed for the F-tests are close to 15 and we therefore consider our instruments to be relevant. Hansen-J tests again support the exclusion restrictions and are conveniently insignificant at least at a 25% level.

4.5.4 Summary of Results from the Simultaneous Equations

4.5.4.1 Simultaneous Risk Management

For banks in the non-trading book sample we find that more restrictive on-balance-sheet IRR management, resulting in lower maturity gaps, and an intensified use of interest rate swaps are substitute strategies. The coefficients derived for the probability of default largely provide an empirical support for the behavior of unconstrained firms in theoretical

Table 4.10: Extent of Interest Rate Swap Use - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
	Panel A				*Panel B*			
Modified duration gap	1.554***	1.304***	1.035***	1.499***	1.477***	1.283***	0.979***	1.441***
	(0.3632)	(0.3597)	(0.3609)	(0.4060)	(0.3761)	(0.3658)	(0.3617)	(0.4117)
Probability of default (ln)	0.024	-0.009	-0.066	-0.005	0.053	0.015	-0.059	0.019
	(0.0303)	(0.0282)	(0.0584)	(0.0379)	(0.0345)	(0.0307)	(0.0524)	(0.0389)
Size	1.558***	1.366***	0.933**	1.878***	1.784***	1.785***	1.049**	2.293***
	(0.4153)	(0.4118)	(0.4378)	(0.5360)	(0.3980)	(0.4094)	(0.4085)	(0.5192)
Total asset growth	-0.425	0.209	-1.667***	-0.515	0.072	0.621	-2.004***	-0.149
	(0.4729)	(0.5070)	(0.6208)	(0.6655)	(0.4867)	(0.5033)	(0.5430)	(0.6601)
Savings deposits	-0.062	0.121	1.006	1.097	1.173	0.953	1.264	2.039**
	(0.6801)	(0.7146)	(1.2158)	(0.9627)	(0.7603)	(0.7658)	(1.2240)	(1.0379)
Liquid assets	0.105	-0.064	0.052	-0.085	-0.033	-0.157	-0.043	-0.207
	(0.2464)	(0.2465)	(0.3625)	(0.2776)	(0.2358)	(0.2391)	(0.3350)	(0.2638)
Branch HHI	-0.029*	-0.008	-0.097***	-0.030	-0.011	0.005	-0.077***	-0.007
	(0.0155)	(0.0151)	(0.0328)	(0.0204)	(0.0122)	(0.0125)	(0.0250)	(0.0163)
Past swap experience	2.796***	0.670***	1.005***	0.588***	2.498***	0.717***	1.054***	0.464***
	(0.4153)	(0.2551)	(0.3480)	(0.1269)	(0.3938)	(0.0765)	(0.3553)	(0.1260)
Dummy trading book	0.023			0.003	-0.076			-0.072
	(0.2545)			(0.3967)	(0.2523)			(0.4056)
Inverse Mills ratio	1.648***	-0.024		-0.098	1.390***			-0.345***
	(0.3313)	(0.1938)		(0.1409)	(0.3162)			(0.1320)
Yield curve slope					0.068*	0.072*	0.073	0.090*
					(0.0372)	(0.0385)	(0.0532)	(0.0458)
Yield curve slope x 1-year interest rate					-0.137***	-0.075**	-0.086**	-0.050
					(0.0230)	(0.0297)	(0.0427)	(0.0392)
Time dummies	YES	YES	YES	YES	NO	NO	NO	NO
Adj. GR^2	0.301	0.129	0.461	0.151	0.293	0.120	0.455	0.145
Kleibergen-Paap F-stat.	25.917	25.843	19.659	20.072	23.862	25.960	16.512	18.820
Overidentification stat.	0.213	0.022	1.095	1.147	0.022	0.046	1.283	0.345
p-val.	0.645	0.882	0.295	0.284	0.881	0.830	0.257	0.557
Endogeneity stat.	23.225	10.293	8.838	12.891	18.588	9.044	7.888	11.939
p-val.	0.000	0.001	0.003	0.000	0.000	0.003	0.005	0.001

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Table 4.10 continued: Extent of Interest Rate Swap Use - Simultaneous Time-Series Models

	Total sample	Non-trading book	Trading book	Starters	Total sample	Non-trading book	Trading book	Starters
			Panel C				*Panel D*	
Modified duration gap	1.679***	1.327***	1.054***	1.730***	1.718***	1.344***	1.053***	1.714***
	(0.4115)	(0.3976)	(0.3625)	(0.4784)	(0.4231)	(0.4057)	(0.3595)	(0.4799)
Probability of default (ln)	0.056	0.026	-0.074	0.058	0.047	0.016	-0.073	0.045
	(0.0397)	(0.0385)	(0.0518)	(0.0477)	(0.0405)	(0.0390)	(0.0523)	(0.0477)
Size	1.427***	1.272***	0.950**	1.855***	1.594***	1.445***	0.944**	1.978***
	(0.3620)	(0.3614)	(0.4035)	(0.5153)	(0.3804)	(0.3697)	(0.3984)	(0.5141)
Total asset growth	-0.089	0.198	-1.976***	-0.443	-0.475	-0.021	-1.952***	-0.583
	(0.5325)	(0.5357)	(0.5577)	(0.7263)	(0.5175)	(0.5233)	(0.5695)	(0.7270)
Savings deposits	1.115	0.748	0.860	2.120*	0.535	0.456	0.899	1.886
	(0.8312)	(0.8094)	(1.2710)	(1.1654)	(0.7909)	(0.7916)	(1.2800)	(1.1552)
Liquid assets	-0.113	-0.212	0.044	-0.069	0.020	-0.146	0.047	-0.063
	(0.2427)	(0.2565)	(0.3419)	(0.3007)	(0.2665)	(0.2729)	(0.3468)	(0.3060)
Branch HHI	-0.022*	0.005	-0.083***	-0.006	-0.015	0.007	-0.083***	-0.005
	(0.0121)	(0.0126)	(0.0235)	(0.0174)	(0.0125)	(0.0131)	(0.0233)	(0.0173)
Past swap experience	2.572***	0.431*	1.022***	0.478***	2.670***	0.461*	1.022***	0.474***
	(0.4224)	(0.2383)	(0.3518)	(0.1289)	(0.4486)	(0.2436)	(0.3524)	(0.1295)
Dummy trading book	-0.008			0.017	-0.014			0.003
	(0.2553)			(0.4145)	(0.2587)			(0.4146)
Inverse Mills ratio	1.511***	-0.181		-0.199	1.579***	-0.164		-0.221
	(0.3458)	(0.1780)		(0.1401)	(0.3669)	(0.1841)		(0.1438)
Yield curve slope					-0.078**	0.000	-0.002	0.038
					(0.0379)	(0.0313)	(0.0442)	(0.0366)
EURIBOR spread	0.549***	0.359***	0.368***	0.369***	0.611***	0.455***	0.352***	0.484***
	(0.0786)	(0.0674)	(0.0966)	(0.0831)	(0.0643)	(0.0582)	(0.0939)	(0.0725)
Yield curve slope x EURIBOR spread	0.044	0.098**	-0.015	0.128**				
	(0.0427)	(0.0424)	(0.0688)	(0.0570)				
Time dummies	NO	NO	NO	NO	NO	NO	NO	NO
Adj. GR^2	0.295	0.124	0.456	0.152	0.294	0.123	0.456	0.150
Kleibergen-Paap F-stat.	21.097	22.209	14.980	14.869	20.374	21.539	14.816	14.768
Overidentification stat.	0.272	0.706	1.024	0.029	0.222	0.667	1.008	0.037
p-val.	0.602	0.401	0.312	0.865	0.638	0.414	0.315	0.847
Endogeneity stat.	20.395	8.011	8.570	14.122	20.626	8.031	8.555	13.682
p-val.	0.000	0.005	0.003	0.000	0.000	0.005	0.003	0.000
Observations	7,399	5,725	1,701	3,880	7,399	5,725	1,701	3,880
Banking group dummies	YES	YES	YES	YES	YES	YES	YES	YES

Dependent variable: *extent of interest rate swap use*. All regressions are 2SLS regressions according to the sample selection correction of Semykina and Wooldridge (2010) with *modified duration gap* being instrumented with the *customer loans* and *loan commitments*. Standard errors in parentheses are clustered at bank level and are corrected for potentially small sample size. Significance at the 10%/5%/1% level is marked by */**/***. Cragg-Donald F-stat. is the F-statistic for weak instruments with a critical value of 19.93 taking clustered standard errors into account. Endogeneity stat. is the χ^2-statistic of the Durbin-Wu-Hausman test on the endogeneity of Modified duration gap. Adj. GR^2 is the adjusted generalized (within) R^2 of Pesaran and Smith (1994).

Table 4.11: Summary Hausman Tests

Dependent variable	Modified duration gap		Dummy interest rate swap use			Extent of interest rate swap use	
Sample	Total	Starters	Total	Trading	Starters	Total	Starters
Explanatory Variable							
Maturity gap			endog.	exog.	endog.	endog.	endog.
Dummy interest rate swap use	exog.	endog.					

This table summarizes the results of the Hausman-type tests of the exogenous variables in the simultaneous equations framework.

corporate finance risk management models. However, the proxy for profitable growth opportunities — the growth rate of total assets — is most often insignificant. In robustness checks this also holds for the growth rate of customer loans, and total loans, and if we choose real instead of nominal growth rates by deflating monetary volumes. The market timing behavior we find for the slope of the yield curve is in line with the results Memmel (2011) receives for the overall, combined on-balance-sheet and off-balance-sheet IRR exposures.

4.5.4.2 Exogeneity Tests

Table 4.11 summarizes the results from the exogeneity tests of the potentially endogenous explanatory variables within the simultaneous regression framework. As the results for cross-sectional and time-series regressions do not differ, no differentiation is made. We also display only the results for the total sample and the sample of banks starting to use interest rate swaps for the first time. The only exemption is that the result for trading book institutions in the interest rate swap use probit regressions as it differs from the results for exogeneity tests for the total and non-trading book sample.

The decision to use interest rate swaps is only endogenous to the maturity gap for the sub-sample of banks that start hedging during the sample period. These results are robust if we replace the dummy of current swap use by the volume of swaps scaled by total assets. For all other banks, including the total sample which is dominated by banks that either use interest rate swaps in all years or in not a single year, the decision is exogenous. The duration gap is an endogenous determinant of the decision to use interest rate swaps even for starters. It is only for trading book institutions that exogeneity cannot be rejected. With regard to the extent of interest rate swaps held conditional on a positive decision to use interest rate swaps at all, the maturity gap is always endogenous.

We interpret the results as follows. The decision to use interest rate swaps and the extent of their use seem mainly driven by the contemporaneous IRR regulation in Germany, whereas the maturity gap seems to be largely determined by borrower and lender liquidity preferences. Banks that face the decision to newly start employing interest rate swaps are likely to have a maturity gap close to the threshold of being considered an "outlier" bank by the regulator. "Outliers" lose more than 20% of their regulatory equity in a simulated 130 basis point parallel upward shift of the yield curve.[35] Starters face the decision of paying the one-time initial cost of establishing a derivatives hedging department, becoming an "outlier" bank that exceeds the regulatory threshold[36] or, alternatively, rejecting the

[35] The IRR regulation was revised in the fourth quarter of 2011. The relevant interest rate shock has been increased to 200 basis points and banks are no longer referred to as "outliers" but as institutions with "elevated interest rate risk". For more details of the IRR regulation, see Deutsche Bundesbank (2012). Excluding observations from the end of 2011, when the new regulatory framework became effective, does not change our results.

[36] The effects of being classified as an "outlier" by the regulator on the overall IRR exposure have been documented by Memmel (2011). Banks decrease overall IRR exposure drastically afterwards.

loan maturity borrowers demand. In contrast, banks whose exposure is far away from the threshold or those whose exposure is above the threshold but which have already initiated an OBS risk management desk in order to comply with the IRR regulation can offer any loan maturity borrowers demand and accept all volumes of short-term deposits. Hence, only for starters the decision to use interest rate swaps is endogenous to the maturity gap.

The IRR regulation in Germany can also explain the more pronounced use of interest rate derivatives in Germany compared to the U.S., although the intertemporal smoothing theory of Allen and Gale (1997) predicts a higher propensity of derivative use for the U.S., German commercial banks seem to use interest rate swaps predominantly for compliance with the IRR regulation and not to manage liquidity risk.[37]

We additionally interpret the finding that the interest swap use dummy is exogenous for most samples to the fact that German commercial banks' maturity mismatch is largely determined by customers' liquidity needs. Research on borrowers' preferences reveals that loan size is most sensitive to the maturity being offered, whereas interest rate sensitivity is less pronounced. These findings are interpreted as the existence of binding borrower liquidity constraints (e.g., Karlan and Zinman, 2008; Attanasio et al., 2008). Germany's legal and institutional environment provide banks with incentives to supply borrowers with long-term liquidity if demanded. In the German bank-dominated financial system only few large corporates have access to equity and debt capital markets, whereas the majority of Germany's small and medium-sized enterprises, known as the "Mittelstand",

[37] We are not aware of a similar "outlier" threshold with regard to a potential equity loss in the Economic Value Model applied by the Federal Reserve to investigate U.S. commercial banks' IRR, although also a 200 basis point shift in the yield curve is also simulated. The threshold seems more likely to be one comparing banks relative IRR (Houpt and Embersit, 1991) than an absolute one.

depend completely on banks with which they most often have longstanding relationships. Additionally households have most of their savings as deposits with banks (e.g., Allen and Santomero, 2001).

Major determinants of the loan maturity being granted by a bank are the degrees of information asymmetry and moral hazard that are inherent to the borrower relationship. Ways to mitigate the maturity-reducing impact of the aforementioned factors are pledging collateral and relationship lending. The German "Hausbank" principle is one of the strongest forms of relationship lending. Additionally, most often commercial property or real estate is pledged as collateral and valued quite conservatively. Therefore, German banks are likely to offer the same long-term loans as banks in the U.K., although Germany offers less favorable creditor rights (Davydenko and Franks, 2008; Qian and Strahan, 2007). The property rights prevailing in Germany are among the most friendly what additionally facilitates granting long-term loans (Bae and Goyal, 2009). To sum up, the German legal and institutional environment helps to reduce moral hazard, and therefore banks seem to be able and willing to offer their lenders the maturities they demand. Given this setting, it appears plausible that the decision to use swaps is exogenous to the maturity gap except for those banks that face the decision to set up a derivatives department for the first time. Banks at the "outlier" threshold which decide to manage IRR solely on the balance sheet are likely to use their interbank lending and borrowing to adjust their maturity gap endogenously (Ehrmann and Worms, 2004).

Our findings thus confirm that banks use interest rate swaps predominantly for hedging purposes in compliance with IRR regulation. Pure banking book institutions seem at first to choose the magnitude of their maturity gap based on liquidity demand. Afterwards, they decide on the extent of swaps that is necessary in order not to exceed the “outlier” threshold. With regard to the set-up of our simultaneous equation framework, we summarize that the decision to use swaps and the maturity gap do not necessarily have to be estimated simultaneously, except for banks that start using derivatives for the first time.

4.6 Conclusion

Modeling German commercial banks’ IRR management as the simultaneous choice of on-balance-sheet maturity gap management and OBS interest rate swap use, we find that both decisions serve as substitutes for one another. The effect of bankruptcy risk on risk management decisions is consistent with the predictions of corporate finance models for financially unconstrained firms. Being faced with a higher default likelihood makes banks pursue more conservative on-balance-sheet portfolio management with less maturity mismatch, and increases their propensity to hedge on-balance-sheet risk with interest rate swaps.

Our empirical findings are largely in line with those of Purnanandam (2007) who investigates IRR management for U.S. commercial banks. One major exemption is the effect that liquid assets have on the use of interest rate derivatives. U.S. banks manage buffer stocks of liquid assets as substitutes to OBS hedging in line with the theoretical impact predicted by dynamic risk management theories. German commercial banks, on the other hand, consider liquidity buffers complementary risk management strategies to the decision to hold interest rate swaps. Once banks decide to employ interest rate swaps, the extent of their use serves as a substitute for liquid assets. The differences in managing liquidity and interest rate risk on the balance sheet or off the balance sheet have been stressed by Allen and Santomero (2001) based on the theoretical model of Allen and Gale (1997). U.S. banks are more likely to manage risks using derivative hedging, whereas German banks can rely more heavily on on-balance-sheet risk management due to intertemporal smoothing.

The reason why we nevertheless observe more commercial banks in Germany using OBS risk management instruments than in the U.S. is the outcome of the IRR regulation in Germany. Exogeneity tests on the endogenous regressors in the simultaneous equations suggest that swap use is exogenous to the magnitude of the duration gap. Hence, banks seem first to decide on their duration gap, which is driven by the liquidity preferences of their customers. Afterwards, they make their decisions on using interest rate swaps. This holds for all banks, except for banks that start using interest rate swaps for the first time. Only these banks simultaneously decide on their maturity mismatch and the use of interest rate swaps.

We find market timing behavior in IRR management in samples of banks that are by law prohibited from engaging in substantial OBS speculation. Our results show that banks are willing to take more IRR when a steep yield curve makes maturity transformation profitable. Funding uncertainty in the interbank markets urges banks to reduce on-balance-sheet risk by means of derivatives hedging. High levels of short-term nominal interest rates induce banks to further reduce IRR exposure. This finding is consistent with the risk-taking channel of monetary policy. Including macroeconomic variables does not change the relationship between on-balance exposure and interest swap use decisions, and therefore the speculative element in market timing appears minor compared to the dominant effect that on-balance and off-balance IRR management serve as substitutes.

Our research has strong implications for banking supervisory authorities as the design of IRR regulation has a major impact on banks' decision to hedge on-balance-sheet risk with OBS derivatives. As OBS derivatives only allow for trading the interest rate but not (fully) the liquidity risk, there is room for future research to investigate how a combined interest rate and liquidity risk regulation, as proposed by Basel III, with the Liquidity Coverage Ratio and the Net Stable Funding Ratio, will affect banks' portfolio structures. For banks in market-based and bank-based financial systems which both adopt Basel III, it will be interesting to observe whether the theoretical predictions from Allen and Gale's model on the relation between liquid assets and OBS risk management still hold after liquidity risk becomes more heavily regulated.

Appendix D

Variable Description

Table D.1 gives an overview of the variables used in the hazard rate model and the interest rate risk management analysis and how these variables were calculated.

Table D.1: Variable Description

Hazard rate model	
Tier 1 capital ratio	Tier 1 capital to total assets
Total bank reserves	Total reserves that qualify as equity to total assets
Dummy reserve reduction	Dummy taking the value 1 if *Total bank reserves* have been reduced
Sector HHI	Herfindahl index of credit portfolio concentration over 14 industry sectors
Dummy hidden liabilities	Dummy taking the value 1 if the bank avoided writing off assets
ROE	Return on equity calculated as operating income to equity
Branch HHI	Herfindahl index of bank branches per county averaged over all counties where the bank runs branches
Dummy savings banks	Dummy taking the value 1 if bank is a savings bank
Dummy cooperative banks	Dummy taking the value 1 if bank is a cooperative bank
LIBOR	12 month LIBOR
Regional GDP growth	Real GDP growth at the state level
IRR management model	
Dependent variables:	
Modified duration gap	Calculated according to Appendix E
Dummy interest rate swap use	Dummy taking the value 1 if the bank used either interest rate or currency swaps once since 1998
Extent of interest rate swap use	ln of the nominal volume of interest rate swaps
Explanatory variables:	
Probability of default (ln)	ln of the probability of default derived from the hazard rate model
Size	ln of total assets
Savings deposits	Savings deposits to total assets
Liquid assets	Liquid assets to total assets
Total asset growth	Growth rate of total assets
Dummy trading book	Dummy that takes the value 1 if a bank is qualified according to the German Banking Act
Inverse Mills ratio	Inverse Mills ratio is calculated according to Wooldridge (2010) in cross-sectional and according to Semykina and Wooldridge (2010) in time-series models
Customer loans	Customer loans to total assets
Loan commitments	Loan commitments to total assets
Past swap experience	Dummy that takes the value of 1 when a bank used either interest or currency swaps once in previous years since 1998. This variable is adjusted for mergers and assigns a 1 if one of two merging banks had swap experience.
Avg. board experience	This variable is the average experience measured in years of all board members. Experience encompasses all positions in banking where candidates need to be approved by the German Federal Financial Supervisory Authority BaFin.
Yield curve slope	The spread between the 10 year and the 1 year yield of German government bonds
1-year interest rate	The 1-year yield on German government bonds
LIBOR spread	The spread between the 12-month LIBOR and the 12-month German government yield

Appendix E

Modified Duration Gap

Time-to-maturity is defined either as the remaining time-to-maturity or as the time remaining until the next repricing. The modified duration gap is calculated by first assigning the modified durations of the standard BaFin approach to the maturity brackets, and then summing up the volume-weighted assets' and liabilities' time-to-maturity brackets. The modified duration gap can then be calculated from the modified asset and liability duration by

$$D_{gap} = D^{A}_{mod} - D^{L}_{mod} \frac{\textit{total interest-earning liabilities}}{\textit{total interest-paying assets}},$$

where total interest-bearing assets (liabilities) is the sum of business volume reported in the time-to-maturity brackets. Information on assets' remaining time to maturity is available for loans to banks and non-banks. For liabilities' remaining time to maturity in addition to loans from banks and non-banks, savings accounts and bonds issued are also available. For each of these categories, four maturity brackets have been collected ranging from three months or less, more than three months up to one year, more than a year up to five years, and finally, more than five years. The interest rate sensitivities assigned to these brackets are 0.16%, 0.71%, 3.07%, and 5.08%, respectively. In order to eliminate unrealistic outliers, we drop all banks that report negative volumes in any of the time-to-maturity brackets. Additionally, we require that three out of the four brackets reported for loans to and from non-banks have non-zero volume.

Chapter 5

Conclusion and Summary

This thesis consists of a literature review on banks' IRR, and two essays dealing with how banks should price the IRR from maturity transformation into their loan and deposit rates, and how OBS hedging via interest rate swaps affects banks' on-balance-sheet duration gap.

In an extension of the Ho-Saunders models, we show in Chapter 3 how managing the maturity gap affects banks' loan and deposit pricing. Our model predicts that financial intermediaries demand risk premia for the maturity mismatch they bear on the asset side, but reduce their charges if maturity transformation is expected to earn excess returns. For deposits, the opposite holds. As deposits possess longer maturities than funding from the money markets, banks should optimally give depositors risk discounts, but should also price the expected income from maturity transformation forgone.

Empirically, we test our model for the German commercial banking sector. We find the model-derived pricing behavior in banks' interest income, as a proxy of the average loan rate. However, the effects found for for banks' interest expenses, as a proxy for deposit pricing, are only weakly pronounced and most often insignificant. As a third measure of interest pricing, we investigate the net interest income margin, and find the theoretically predicted effects as for the interest margin. Thus, by disentangling net interest income into income and expenses, we show that risk and return from maturity transformation are largely priced through the asset side into banks' overall profitability.

As liabilities usually do not fully offset the IRR from loans, interest rate swaps can be an additional way to hedge it off the balance sheet. In Chapter 4, we analyze German commercial banks' IRR management as the simultaneous decisions of the magnitude of the duration gap and the use of interest rate swaps. Our empirical findings show that banks predominately use interest rate swaps for hedging purposes as a substitute strategy for managing IRR on the balance sheet. However, although hedging motives dominate, we do find mild speculation in the form of selective hedging in response to the macroeconomic environment. Banks decrease their hedging attempts with a steep slope of the yield curve, but intensify them when interbank funding spreads, as an indicator of wholesale funding uncertainty, rise.

Hausman-type exogeneity tests of the dependent variables in the simultaneous equations framework show that the decision of the duration gap and the use of interest rate swaps are not necessarily endogenous to one another. Only banks that start using interest rate swaps for the first time face a situation where both decisions are, indeed, endogenous. For banks that also engage in trading activities, both decisions appear to be exogenous to one another. As these banks might use interest rate swaps at least partly also for speculative purposes, the result seems plausible. For all other commercial banks, the duration gap is an endogenous determinant of the decision to use interest rate swaps, but the use of swaps is exogenous to the duration gap.

We interpret the results from exogeneity tests as follows. The decision to use interest rate swaps is largely driven by the IRR regulation proposed by the Basel Committee with its given “outlier” threshold. Therefore, only banks that never used interest rate swaps before but exceeded the threshold face a situation of reciprocal endogeneity. For the other commercial banks that do not engage in substantial trading, the decision to use swaps is exogenous when deciding on the magnitude of the duration gap. Banks’ maturity gap seems for these banks to be driven by borrowers’ liquidity needs.

Given these results, it might be interesting in future research to examine the impact of the newly proposed liquidity regulation within Basel III, namely the Net Stable Funding Ratio and the Liquidity Coverage Ratio, on banks pricing as well as OBS hedging decisions in view of liquidity risk’s close relation to IRR. The associations of the savings and cooperative banks argue that the new liquidity regulation will force them to lower their maturity gaps and will diminish their future profitability. Some bank managers even argue that their whole business models are threatened. Thus, IRR will remain a timely topic in financial intermediation research in the future.

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